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SITE-SPECIFIC TECHNICAL REPORT FOR BIOSLURPER TESTING AT SITE SS27/XYZ, DOVER AFB, DELAWARE

DRAFT

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
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SITE-SPECIFIC TECHNICAL REPORT (A003)

for

SHORT-TERM PILOT TEST FOR THE BIOSLURPER INITIATIVE AT DOVER AFB, DELAWARE

by

A. Leeson, J.A. Kittel, G. Headington, and J. Eastep

for

Mr. Patrick Haas
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November 10, 1995

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Contract No. F41624-94-C-8012

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EXECUTIVE SUMMARY

This report summarizes the field activities conducted at Dover AFB, for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Dover AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Dover AFB is one of at least 35 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Dover AFB were skimmer pumping, bioslurping, and drawdown pumping.

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing, soil sampling, soil gas permeability testing, and in situ respiration testing.

After the site characterization activities, the pilot tests for the skimmer pumping, bioslurping, and drawdown pumping were conducted. The bioslurper system was installed in existing monitoring well DM 344. The pilot test sequence was as follows: 22 hours in the skimmer configuration, approximately 86 hours in the bioslurper configuration, and an additional 44 hours in the skimmer configuration. Drawdown pumping could not be performed because the well recharged too quickly. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken

throughout the testing. The volumes of LNAPL recovered and groundwater extracted were quantified over time.

Skimmer pumping was not as effective as bioslurping at recovering LNAPL from this site. Free product recovery rates decreased steadily during skimmer pumping, beginning at a rate of approximately 40 gallons/day during the initial skimmer pump test and decreasing to approximately 7 gallons/day by the end of the second skimmer pump test. In contrast, free product recovery rates during the bioslurper pump test remained relatively stable at approximately 45 gallons/day.

Groundwater recovery rates during the bioslurper pump test were high in comparison to rates during the skimmer pump tests. On average, groundwater was extracted at rates of 2,800 gallons/day during bioslurping and 400 gallons/day during skimming.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased significantly at all monitoring points (Table 7). Oxygen concentrations at monitoring point D-MPB-9.0′ did not change significantly during testing, which may be due to an area of low permeability. These results correlate with results from the soil gas permeability test.

Implementation of bioslurping at the Dover AFB test site probably would facilitate enhanced recovery of LNAPL from the water table and simultaneous in situ biodegradation of hydrocarbons in the vadose zone via bioventing. However, bioslurping will result in a vapor stream requiring treatment and the extraction of significant quantities of groundwater, which will increase cost. An economically viable method of treating the off-gas and the extracted water must be found before a long-term test is feasible. The ICE vapor treatment equipment appeared to be a cost effective alternative. ~~[illegible]~~ ICEs, as opposed to standard thermal or catalytic combustors, ~~[illegible]~~ ICEs can treat higher concentrations like those observed at Dover (23,000 ppmV). ~~Based on~~ The supplemental fuel usage rates over the 4 day bioslurper operation indicates that influent vapor concentrations decreased over time.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)

for

SHORT-TERM PILOT TEST FOR THE BIOSLURPER INITIATIVE
DOVER AFB, DELAWARE

November 10, 1995

1.0 INTRODUCTION

This report describes activities performed and data collected during a field test at Dover Air Force Base (AFB), Delaware, to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Dover AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at Dover AFB is one of at least 35 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the *Test Plan and Technical Protocol for Bioslurping* (~~Battelle~~ AFCEE or Kittel et al, 1995). Test provisions specific to activities at Dover AFB were described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping

technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Dover AFB were skimmer pumping, bioslurping, and drawdown pumping. The specific test objectives, methods, and results for the Dover AFB test program are discussed in the following sections.

1.2 Testing Approach

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence: 22 hours in the skimmer configuration, approximately 86 hours in the bioslurper configuration, and an additional 44 hours in the skimmer configuration. Drawdown pumping could not be performed because the well recharged too quickly. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

2.0 SITE DESCRIPTION

Site SS27/XYZ is the Fuel Pump Station (Building 950) located near the northwest end of the northwest/southeast runway and the fueling pads, X, Y, and Z. Underground fuel lines connect the pump station to hydrants on the fueling pads. The pump station has primarily contained JP-4 jet fuel. Base personnel observed free product floating on water in manholes, which led to an initial site investigation.

Site SS27/XYZ contains a minimal amount of surface fill material over primarily fine to medium sand changing with depth to coarse/very coarse sand to a depth of 25 to 35 ft. Discontinuous lens of clay and of gravel also are present. Depths to groundwater range from approximately 10 to 12 ft below ground level (bgl).

Figure 1 illustrates the locations of permanent monitoring wells and cone penetrometer test (CPT) points. Free product was detected at a thickness of 6.88 ft in monitoring well DM 344 and was detected at CPT-15S and CPT-18S, although no measurement of thickness could be made.

What about Well 59S?

A soil gas survey also was conducted at this site in 1989. Concentrations up to 100,000 μg/L were found primarily around the fuel lines. Groundwater at this site has been found to be contaminated with petroleum hydrocarbons up to concentrations of 80,000 μg/L. Soil samples collected via cone penetrometer testing in 1995 have contained Total concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) ranging from 0.002 mg/kg up to 110 mg/kg and total petroleum hydrocarbon (TPH) concentrations of 0.1 to 1,100 mg/kg (Figure 2).

3.0 BIOSLURPER SHORT-TERM PILOT TEST METHODS

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at Dover AFB.

3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring well DM 344 was evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon™ bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored for approximately 6 hours using the oil/water interface probe.

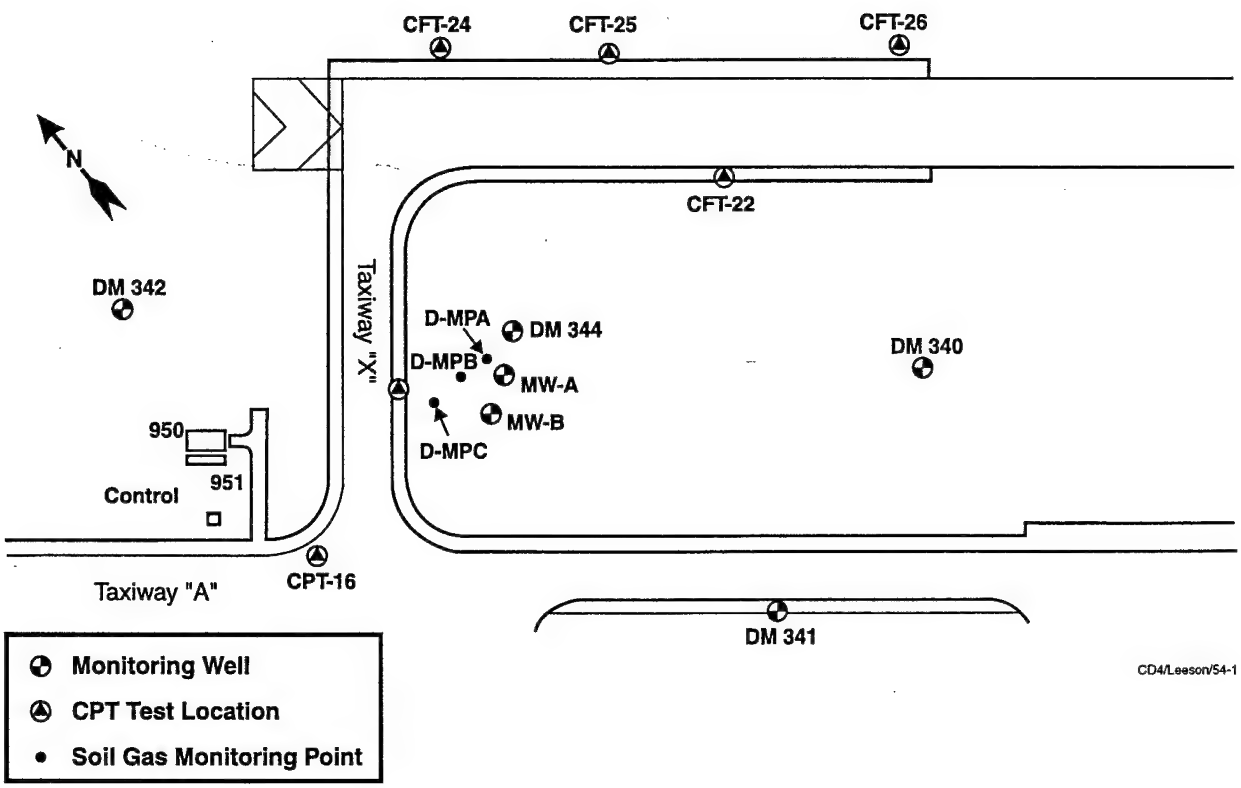

Figure 1. Locations of Permanent Groundwater Monitoring Wells and Cone Penetrometer Test Points at Site SS27/XYZ, Dover AFB, DE

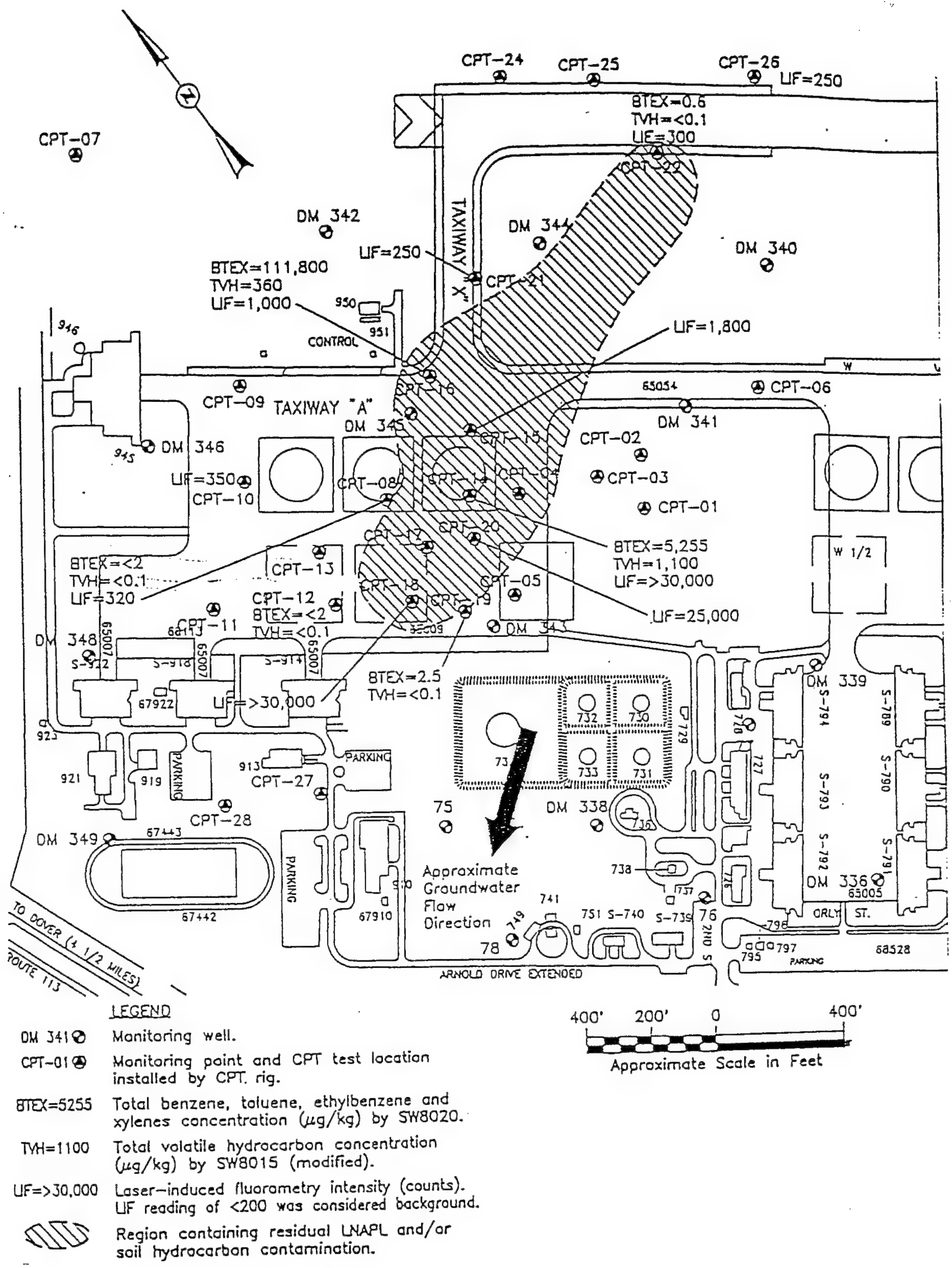

Figure 2. **Soil Hydrocarbon Contamination as Indicated by Cone Penetrometer/Laser-Induced Fluorescence Sensor Results and Laboratory Analytical Results at Site SS27/XYZ, Dover AFB, DE**

An LNAPL sample was collected after completing the baildown test and was labeled FUEL #1 (JP4). The sample was sent to Alpha Analytical, Inc., Sparks, Nevada for analysis of BTEX, TPH, and boiling point fractionation.

3.2 Well Construction Details

Existing monitoring well DM 344 was selected for use in the bioslurper pilot testing. The well is constructed of 2-inch-diameter, schedule 40 polyvinyl chloride (PVC) with a total depth of 18 ft and 10 ft of screen. A schematic diagram illustrating well construction details is provided in Figure 3.

3.3 Soil Gas Monitoring Point and Thermocouple Installation

On August 22, 1995, three monitoring points were installed in the area of monitoring well DM 344 and were labeled D-MPA, D-MPB, and D-MPC. The locations and construction details of the monitoring points are illustrated in Figures 2 and 3, respectively.

The monitoring points consisted of sets of ¼-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at the appropriate depths, and the annular space corresponding to the screened length was filled with silica sand. The interval between the screened lengths was filled with bentonite clay chips, as was the space from the top of the shallowest screened length to the ground surface. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal.

All monitoring points were installed in a 6-inch-diameter borehole to a depth of 9.25 ft. Screened lengths were placed at three depths: 2.5 to 3.0 ft, 5.5 to 6.0 ft, and 8.5 to 9.0 ft. Three type K thermocouples were installed in monitoring point D-MPA at depths of 3.0, 6.0, and 9.0 ft.

After installation of the monitoring points, initial soil gas measurements were taken with a GasTechtor portable O_2/CO_2 meter and a GasTech Trace-Techtor portable hydrocarbon meter. In general, oxygen limitation was observed at the deeper depths, with oxygen concentrations ranging from 0% to 4.5% at a depth of 9.0 ft (Table 1).

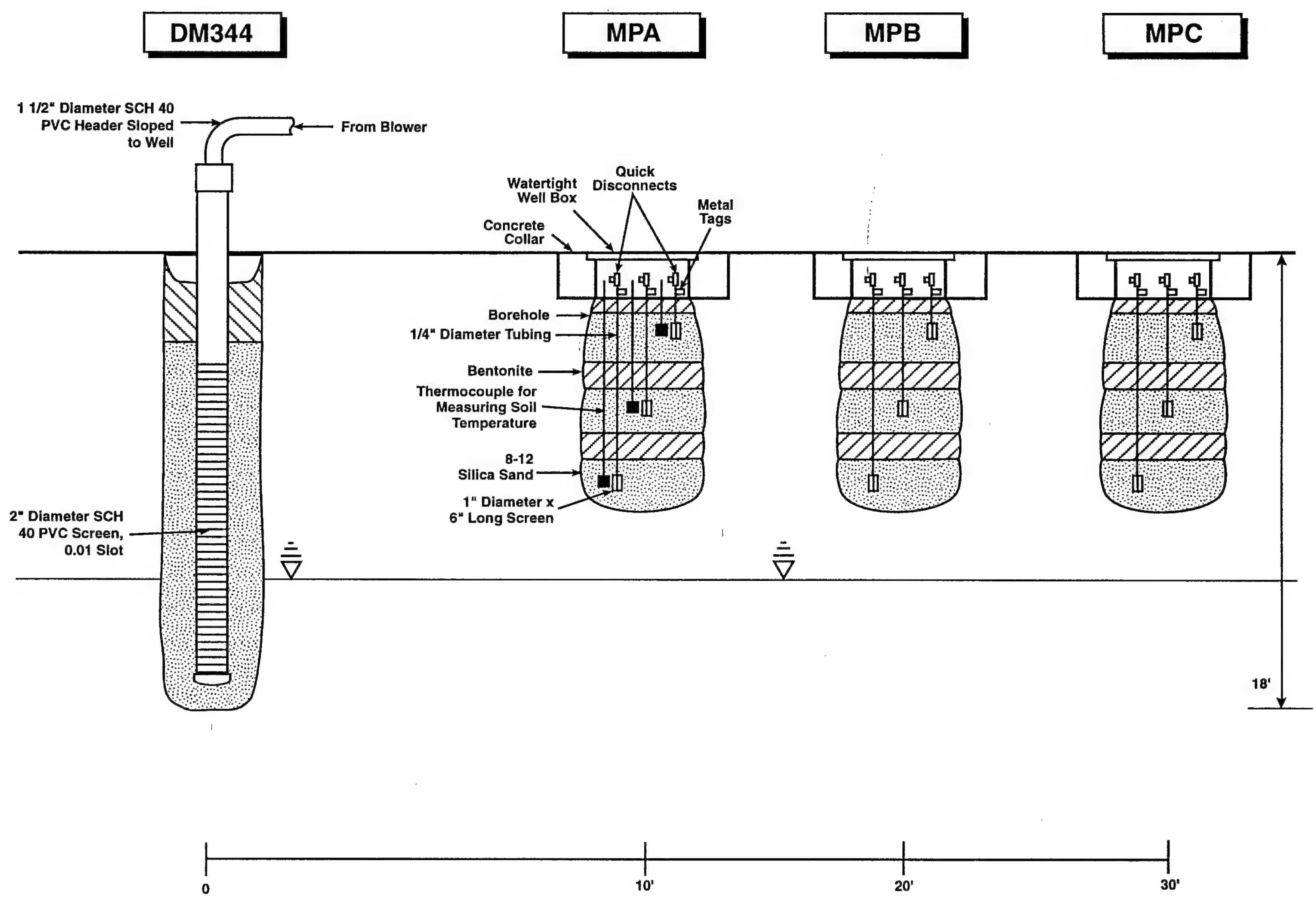

Figure 3. Schematic Diagram Illustrating Site Lithology and Construction Details of the Bioslurper Well and Soil Gas Monitoring Points at Site SS27/XYZ, Dover AFB, DE

F/Leeson/54-2

Table 1. Initial Soil Gas Compositions at Site SS27/XYZ, Dover AFB, DE

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)
D-MPA	3.0	15	6.6	16,000
	6.0	1.8	16.0	>100,000
	9.0	3.5	15.0	>100,000
D-MPB	3.0	20.5	0.7	380
	6.0	18.0	3.0	6,800
	9.0	4.5	13.2	>100,000
D-MPC	3.0	3.0	11.0	63,000
	6.0	0.5	14.0	>100,000
	9.0	0.0	16.5	>100,000

3.4 Soil Sampling and Analysis

Six soil samples were collected during the installation of monitoring point D-MPA. The soil samples were collected in brass sleeves driven down the center of the hollow-stem auger used to drill the monitoring well. The samples were labeled as follows: Dover #1-7.5-8.0, Dover #2-8.0-8.5, Dover #3-8.5-9.0, Dover #4-9.0-9.5, Dover #5-9.5-10.0, and Dover #6-10.0-10.5. The samples were placed in insulated coolers, chain-of-custody records and shipping papers were completed, and the samples were sent to Alpha Analytical, Inc., in Sparks, Nevada by overnight express. Samples Dover #3-8.5-9.0 and Dover #6-10.0-10.5 were analyzed for BTEX and TPH. Samples Dover #1 through #3 and Dover #4 through #6 were composited and analyzed for bulk density, moisture content, and porosity. Laboratory analytical reports for all samples are provided in Appendix B.

3.5 LNAPL Recovery Testing

3.5.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), oil/water separator, and required support equipment are carried to the test location on a trailer. The trailer was located near monitoring well DM 344, the well cap was removed, a coupling and tee were attached to the top of the well, and the slurper tube was lowered into the well. The slurper tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping as described in Sections 3.5.2, 3.5.3, and 3.5.5, respectively. An internal combustion engine (ICE) was used to treat the bioslurper system off-gas. Data from the ICE operation is provided in Appendix C. In addition, extracted groundwater was treated by passing the effluent through a bag filter, an oil/water separator, hydrophobic clay drums, and activated carbon drums (Figure 4).

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix D. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix E.

3.5.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface with the wellhead open to the atmosphere via a PVC connecting tee (Figure 5). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on August 24, 1995, to begin the skimmer pump test. The test was operated continuously for approximately 22 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix E.

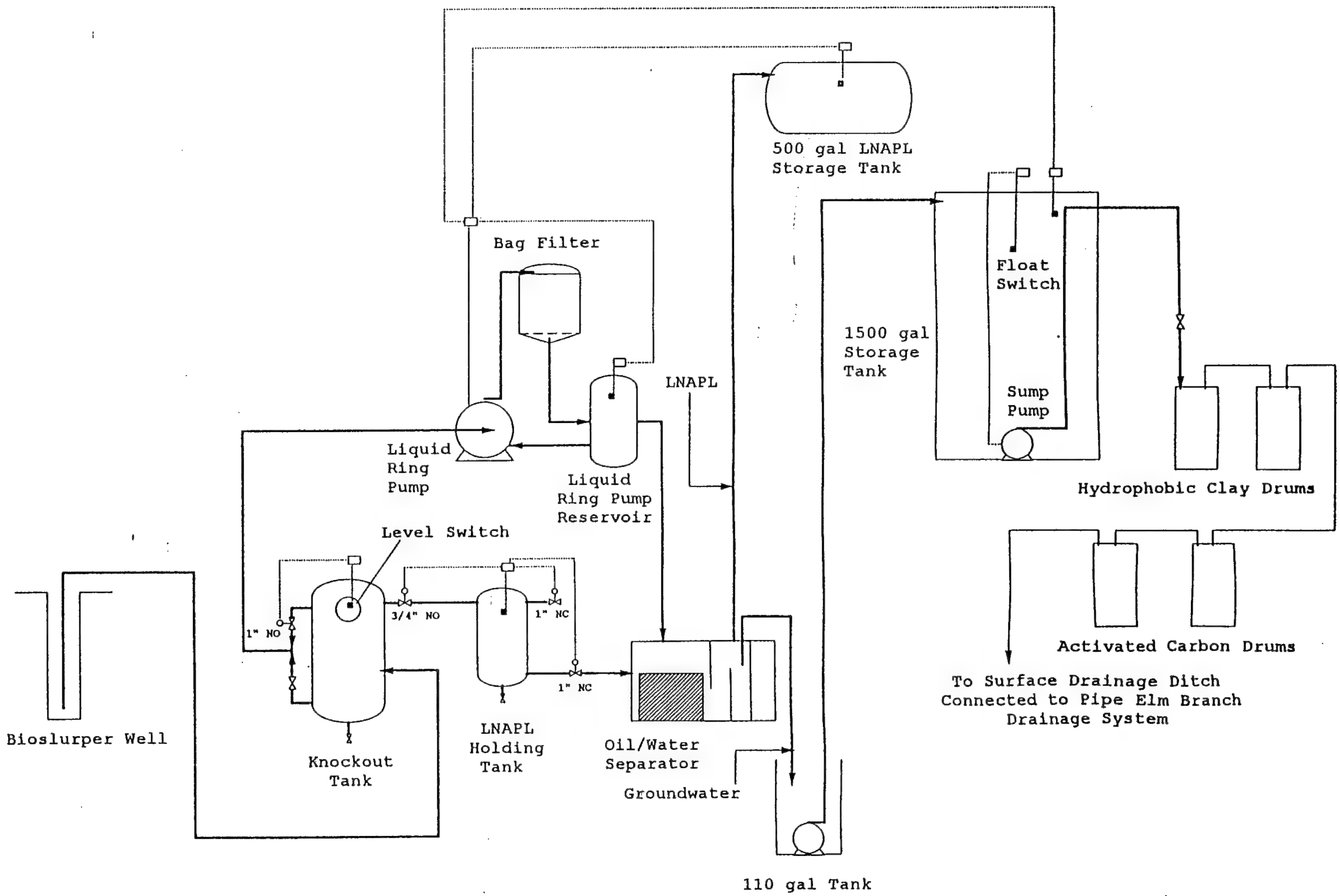

Figure 4. Bioslurper System Process Flow at Site SS27/XYZ, Dover AFB, DE

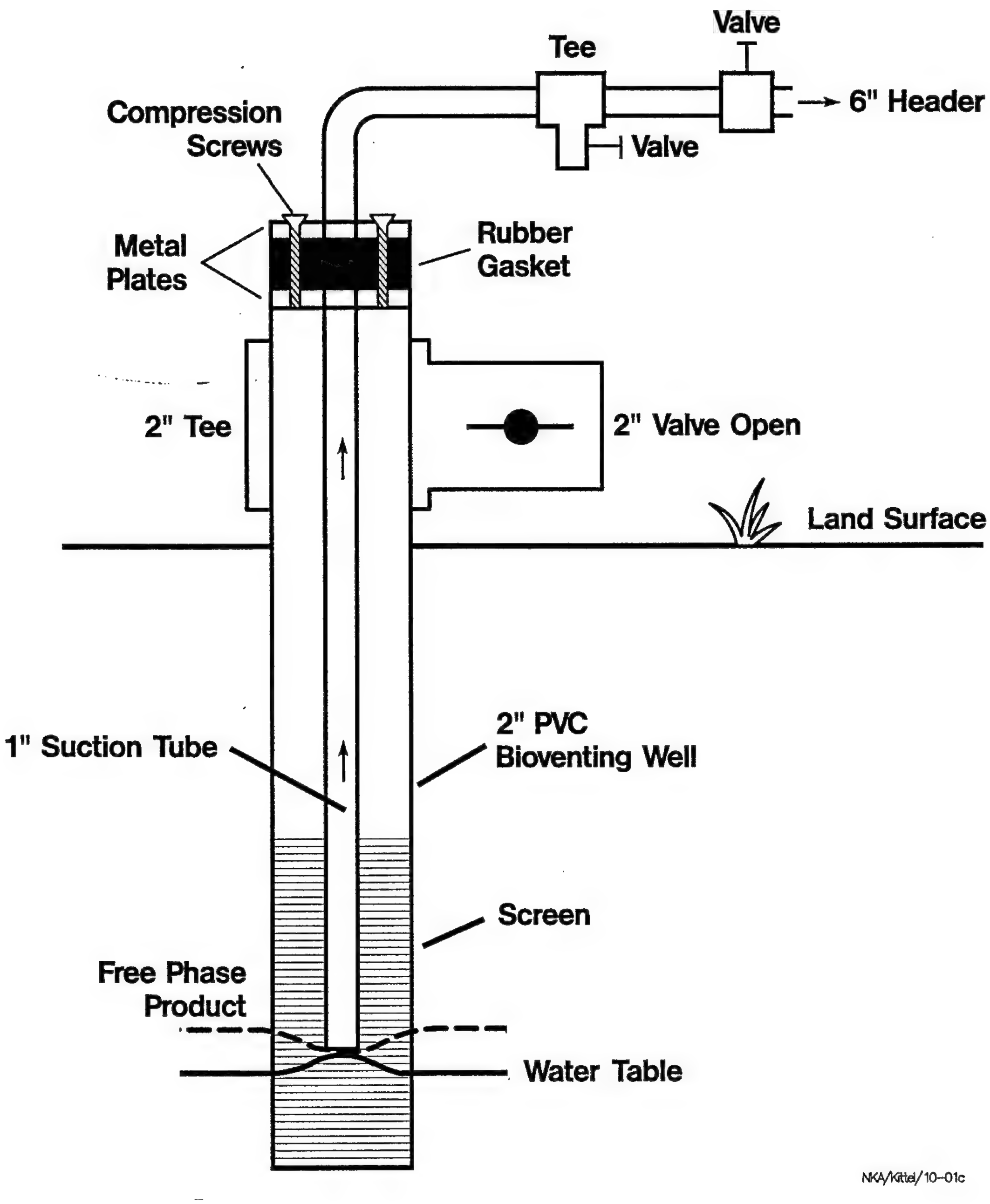

Figure 5. Slurper Tube Placement and Valve Position for the Skimmer Pump Test

3.5.3 Bioslurper Pump Test

Upon completion of the skimmer pump test, preparations were made to begin the bioslurper pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface, as in the skimmer pump test. However, in contrast to the skimmer pump test, the PVC connecting tee was removed, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 6). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on August 25, 1995, to begin the bioslurper pump test. The test was initiated approximately 19 hours after the skimmer pump test and was operated continuously for approximately 86 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix E.

3.5.4 Second Skimmer Pump Test

Upon completion of the bioslurper pump test, preparations were made to begin the second skimmer pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The valve and slurper tube configuration were identical to that used for the initial skimmer pump test. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on August 29, 1995, to begin the second skimmer pump test. The test was initiated approximately 5 hours after the bioslurper pump test and was operated continuously for 44 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix E.

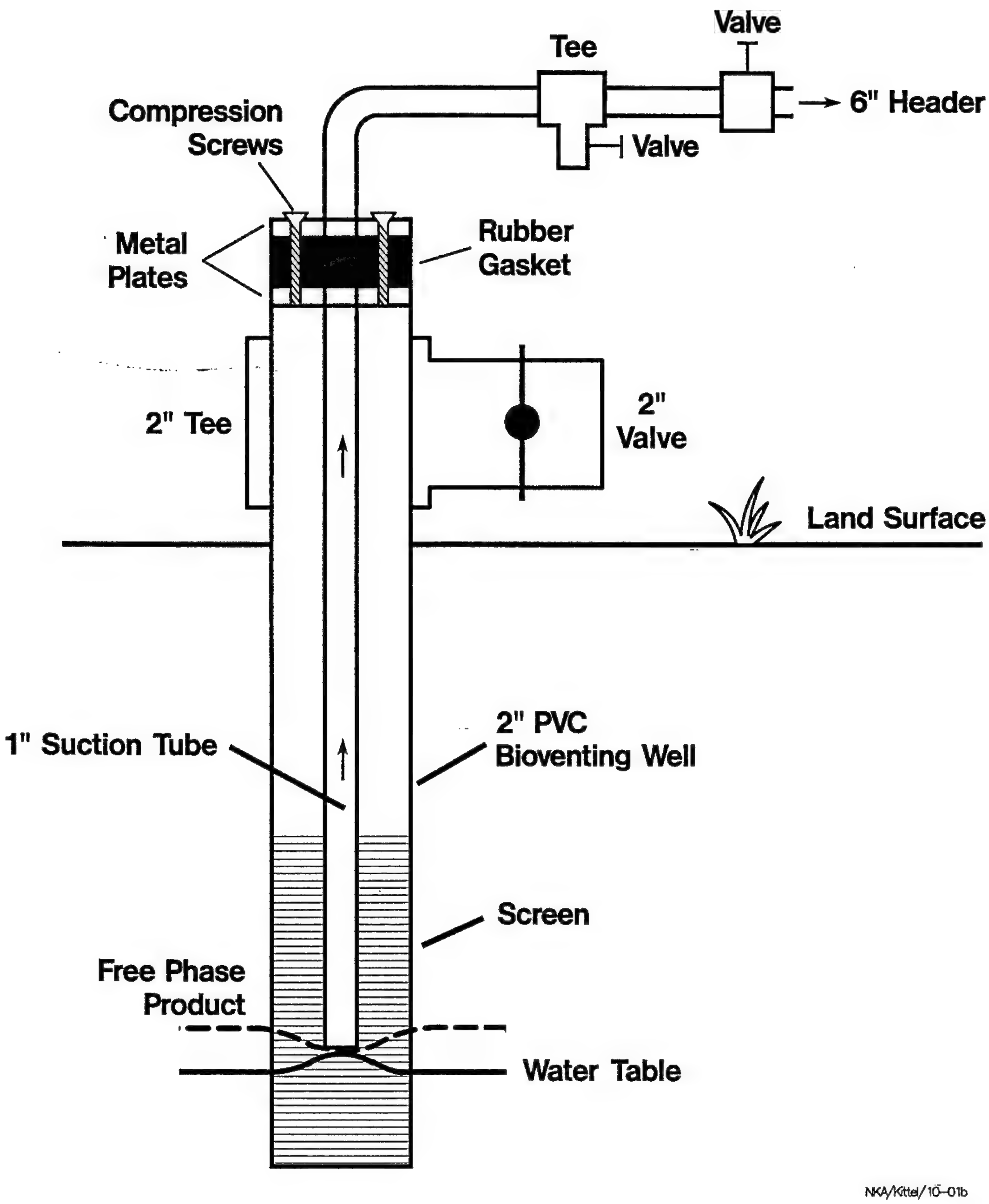

Figure 6. Slurper Tube Placement and Valve Position for the Bioslurper Pump Test

3.5.5 Drawdown Pump Test

Upon completion of the second skimmer pump test, preparations were made to begin the drawdown pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. Typically, the slurper tube is then set so that the tip is approximately 15 inches below the oil/water interface with the PVC connecting tee open to the atmosphere (Figure 7). Attempts were made several times to drawdown monitoring well DM 344. However, the well recharged so quickly, that drawdown could not be accomplished.

3.5.6 Off-Gas Sampling and Analysis

Soil gas samples were collected from the bioslurper off-gas during the bioslurper pump test. Duplicate samples were collected in Summa™ canisters prior to and after treatment through the ICE. Samples were labeled SEAL GAS #1 and SEAL GAS #2 (prior to ICE treatment) and ICE #1 and ICE #2 (after ICE treatment). An additional sample was collected from the ICE when operating on atmospheric air as a blank. This sample was labeled ICE #3-BLK. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

3.5.7 Groundwater Sampling and Analysis

Five groundwater samples were collected during the bioslurper pump test. Two samples were collected after all groundwater treatment and were labeled Effluent #1 and Effluent #2. One sample was collected downstream of the oil/water separator and was labeled OWS-#1. Two samples were collected from the settling tank and were labeled Pretreatment #1 and Pretreatment #2. Samples were collected in 40-mL septa vials containing HCl preservative. Samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH.

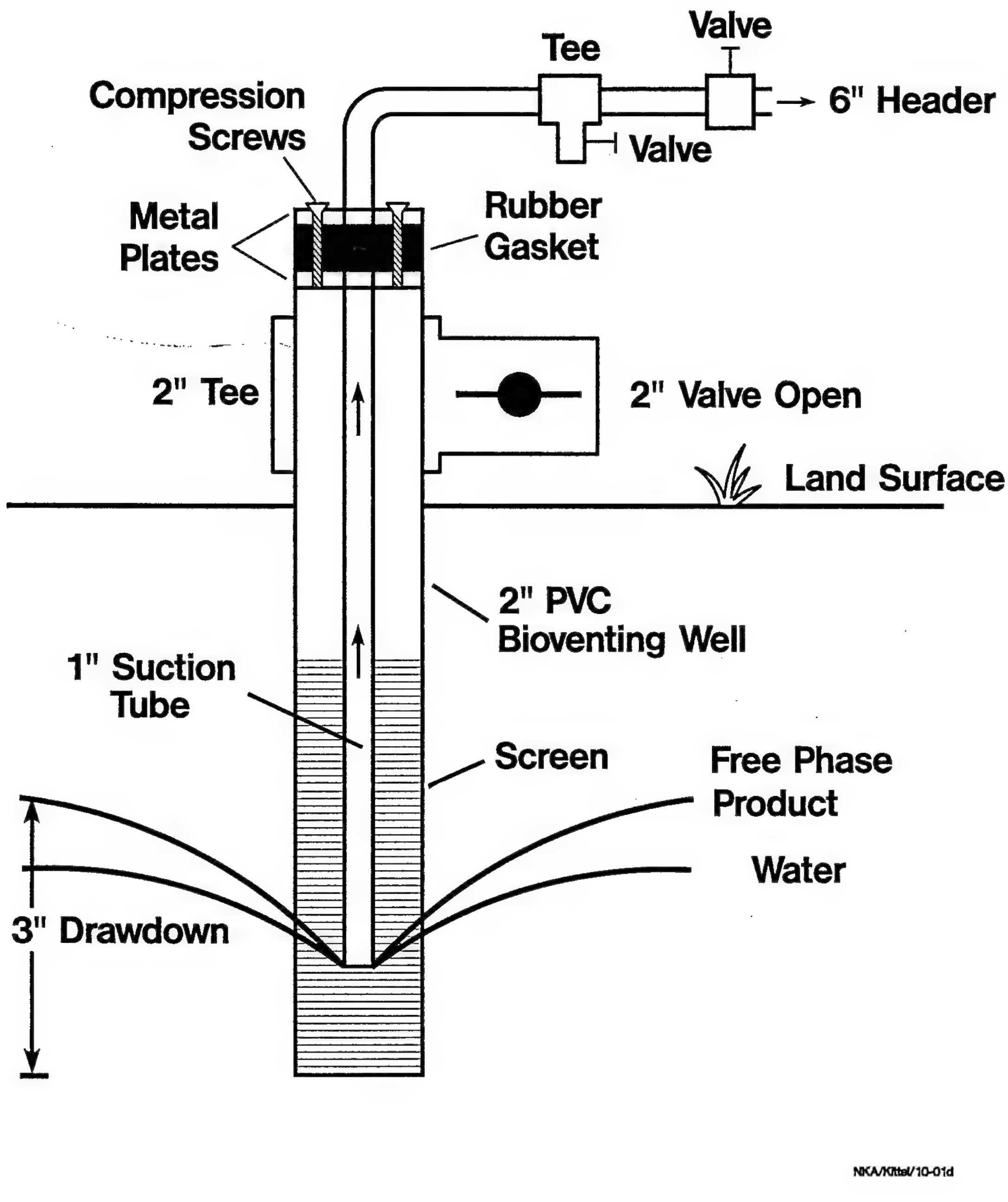

Figure 7. Slurper Tube Placement and Valve Position for the Drawdown Pump Test

3.6 Soil Gas Permeability Testing

The soil gas permeability test data were collected during the bioslurper pump test. Before a vacuum was established in the extraction well, the initial soil gas pressures at the three installed monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well which was the starting point for the soil gas permeability testing. Soil gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil gas pressure data were collected frequently during the first 20 minutes of the test. The soil gas pressures were recorded throughout the bioslurper pump test to determine the bioventing radius of influence. Test data are provided in Appendix F.

3.7 In Situ Respiration Testing

Air containing approximately 2% helium was injected into four monitoring points for approximately 24 hours beginning on August 24, 1995. The setup for the in situ respiration test is described in the *Test Plan and Technical Protocol a Field Treatability Test for Bioventing* (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through the following monitoring points at the depths indicated: D-MPA-6.0′, D-MPB-9.0′, D-MPC-6.0′, and D-MPC-9.0′. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The respiration test was terminated on August 29, 1995. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix G.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate of helium diffusion. As a general rule, we have found that if helium concentrations at test completion

are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

4.0 RESULTS

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at Dover AFB.

4.1 Baildown Test Results

Results from the baildown test in monitoring well DM 344 are presented in Table 2. A total volume of 25.5 L (6.74 gallons) was removed by hand bailing from monitoring well DM 344. The LNAPL thickness recovered rapidly to approximately initial levels by the end of the 6-hour test period. These results indicated that monitoring well DM 344 was suitable for bioslurper field testing.

Table 2. Results of Baildown Testing in Monitoring Well DM 344

Date-Time	Depth to LNAPL (ft)	Depth to Groundwater (ft)	LNAPL Thickness (ft)
Initial Reading 8/21/95-1130	9.22	12.95	3.73
Test Initiation 8/21/95-1155	9.7	11.68	1.98
8/21/95-1330	9.22	12.85	3.63
8/21/95-1800	9.19	12.96	3.77

4.2 Soil Sample Analyses

Table 3 shows the BTEX and TPH concentrations measured in soil samples collected from Site SS27/XYZ. BTEX and TPH concentrations were relatively high, with an average total BTEX

Table 3. BTEX and TPH Concentrations in Soil Samples from Site SS27/XYZ, Dover AFB, DE

Parameter	Concentration (mg/kg)	
	Dover #3 - 8.5-9.0	Dover #6 - 10.0-10.5
TPH as jet fuel	580	1,300
Benzene	1.2	20
Toluene	5.8	2.4
Ethylbenzene	23	45
Xylenes	5.6	1.2

concentration of 52 mg/kg and an average TPH concentration of 940 mg/kg. The results of the physical characterization of the soils are presented in Table 4.

4.3 LNAPL Pump Test Results

4.3.1 Initial Skimmer Pump Test Results

The LNAPL thickness prior to the initial skimmer pump test was 3.63 ft (Table 5). A total of 35.02 gallons of LNAPL was recovered during this test, with an average recovery rate of 38 gallons/day (Table 6). A total of 170 gallons of groundwater was extracted with an average extraction rate of 185 gallons/day (Table 6). Results of LNAPL recovery versus time are shown in Figure 8.

4.3.2 Bioslurper Pump Test Results

LNAPL recovery rates increased significantly during the bioslurper pump test (Figure 8). The increase in recovery rate indicates that LNAPL was mobilized to the extraction well under vacuum-enhanced conditions. A total of 173 gallons of LNAPL and 10,200 gallons of groundwater were extracted during the bioslurper pump test, with daily average recovery rates of 43 gallons/day

Table 4. Physical Characterization of Soil from Site SS27/XYZ, Dover AFB, DE

Parameter	Sample	
	Comp - Dover #1, #2, and #3	Comp - Dover #4, #5, and #6
Moisture Content (%)	10.4	11.0
Porosity (%)	61.9	61.5
Specific Gravity (g/cm^3)	1.01	1.02

Table 5. Depths to Groundwater and LNAPL Prior to Each Pump Test

Test	Test Start Date	Depth to LNAPL (ft)	Depth to Groundwater (ft)[1]	LNAPL Thickness (ft)
Initial Skimmer Pump Test	8/24/95	10.32	13.95	3.63
Bioslurper Pump Test	8/25/95	11.23	11.59	0.36
Second Skimmer Pump Test	8/29/95	NM	NM	NM

NM = Not measured

Table 6. Pump Test Results at Site SS27/XYZ, Dover AFB, DE

Recovery Rate (gal/day)	Initial Skimmer Pump Test		Bioslurper Pump Test		Second Skimmer Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater
Day 1	38.27	185	35.2	2,794	16.4	432
Day 2	NA	NA	39.87	2,851	11.87	402
Day 3	NA	NA	52.11	2,880	6.9	431
Day 4	NA	NA	45.8	2,851	NA	NA
Average	38.27	185	43.2	2,844	11.7	422
Total Recovered (gal)	35.03	170	172.81	10,238[1]	20.86	782

NA = Not applicable.
1 Meter was malfunctioning. Total volume of groundwater recovered was estimated based on an average rate.

for LNAPL and 2,800 gallons/day for groundwater (Table 6). The LNAPL recovery rate versus time is shown in Figure 9. The vacuum-exerted wellhead pressure on monitoring well DM 344 was kept relatively constant throughout the bioslurper pump test at approximately 6 inches of mercury.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased significantly at all monitoring points (Table 7). Oxygen concentration at monitoring point D-MPB-9.0′ did not change significantly during testing, which may be due to an area of low permeability. These results correlate with radius of influence results from the soil gas permeability test.

Table 7. Oxygen Concentrations During the Bioslurper Pump Test at Site SS27/XYZ, Dover AFB, DE

Monitoring Point	Oxygen Concentrations (%) Versus Time (minutes)					
	0	3.5	22	46	69	91[1]
D-MPA-3.0′	15	17	20.4	20.5	20.9	20.9
D-MPA-6.0′	1.8	2.7	12.5	17.0	18.6	20.0
D-MPA-9.0′	3.5	1.2	7.0	10.0	13.0	20.3
D-MPB-3.0′	20.5	20.5	20	19.5	19.8	19.8
D-MPB-6.0′	18.0	20	18.9	18.5	18.3	18.5
D-MPB-9.0′	4.5	4.0	3.0	4.0	5.0	3.1
D-MPC-3.0′	3.0	8.7	11.5	19.0	19.8	17.3
D-MPC-6.0′	0.5	4.5	4.0	12.1	12.5	9.5
D-MPC-9.0′	0.0	0.0	2.0	4.8	8.0	6.6

[1] One hour after bioslurper pump shut off.

4.3.3 Second Skimmer Pump Test

Totals of 23.86 gallons of LNAPL and 782 gallons of groundwater were recovered during the second skimmer pump test, with daily average recovery rates of 12 gallons/day for LNAPL and 420

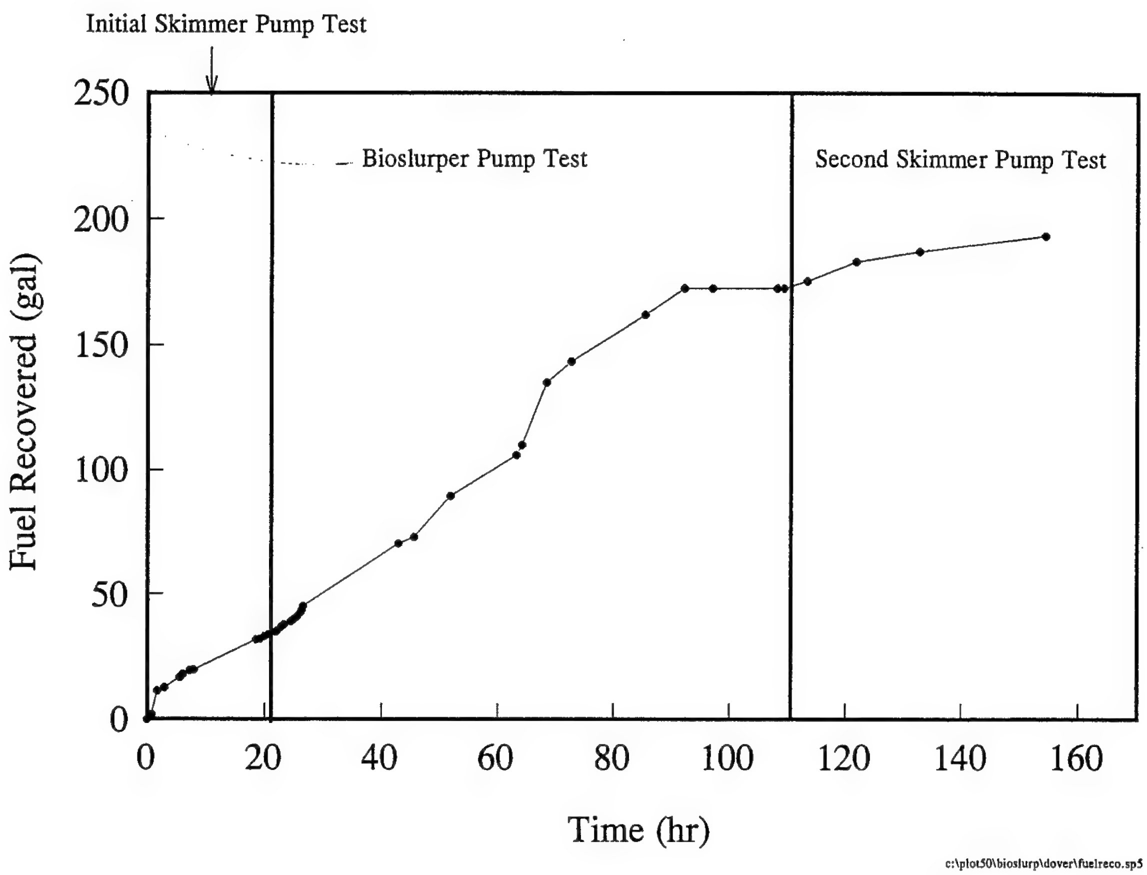

Figure 8. LNAPL Recovery Versus Time During Each Pump Test

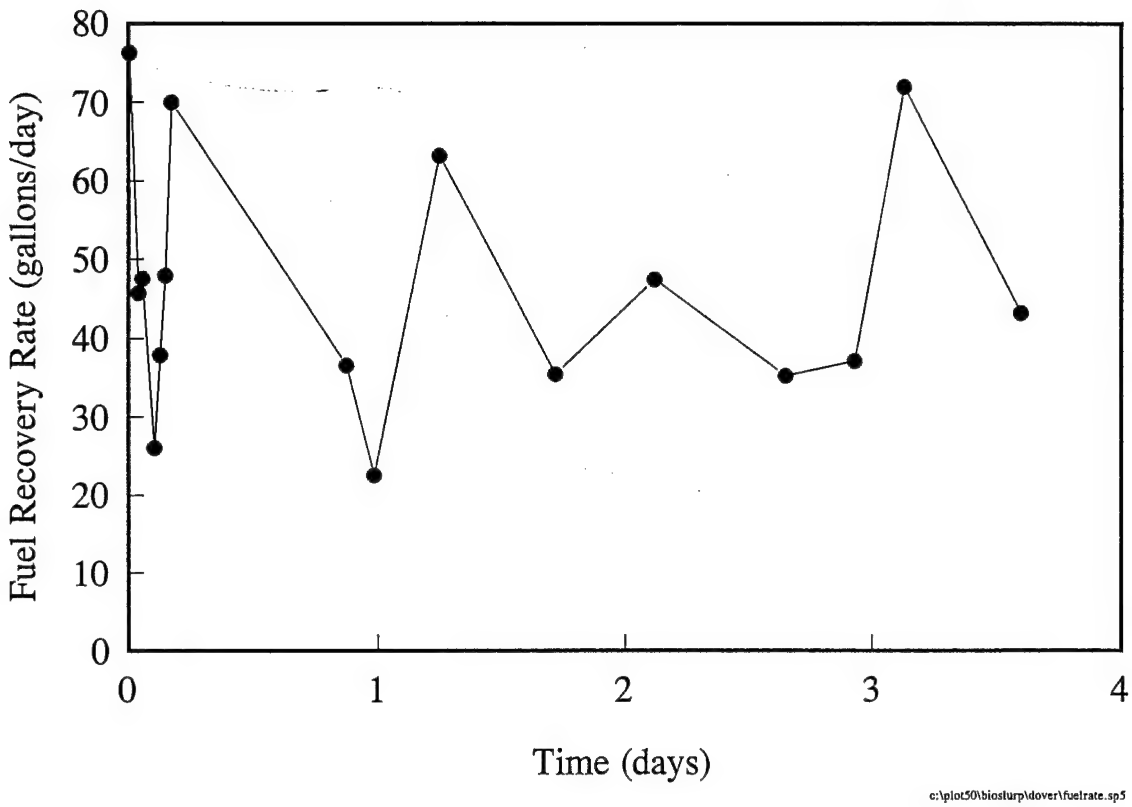

Figure 9. LNAPL Recovery Rate Versus Time During the Bioslurper Pump Test

gallons/day for groundwater (Table 6). These results demonstrate that operation of the bioslurper system in the skimmer mode was not as effective a means of free-product recovery as the bioslurper system at this site.

4.4 Extracted Groundwater, LNAPL, and Off-Gas Analyses

During the bioslurper pump test, groundwater samples were collected at several stages through the groundwater treatment system. Results demonstrated the efficiency of the groundwater treatment system, with BTEX and TPH concentrations reduced by approximately 20% and 80%, respectively by the settling tanks and >99% after all treatment (Table 8).

Off-gas samples from the bioslurper system also were collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 9. These results demonstrated the treatment efficiency of the ICE unit, with >99% destruction of BTEX and TPH. Given a vapor discharge rate of 78 scfm and using an average concentration of 110 ppmv TPH, approximately 4.4 lb/day of TPH was emitted to the air during the bioslurper pump test. Benzene emissions were approximately 0.019 lb/day.

The composition of LNAPL is shown in Tables 10 and 11 in terms of BTEX concentrations and distribution of C-range compounds, respectively. The distribution of C-range compounds is shown graphically in Figure 10.

4.5 Bioventing Analyses

4.5.1 Soil Gas Permeability and Radius of Influence

The radius of influence is calculated by plotting the log of the pressure change at a specific monitoring point versus the distance from the extraction well. The radius of influence is then defined as the distance from the extraction well where 0.1 inch of H_2O can be measured. Based on this definition, the radius of influence at this site is approximately 37 ft (Figure 11).

Table 8. **BTEX and TPH Concentrations in Extracted Groundwater During the Bioslurper Pump Test at Site SS27/XYZ, Dover AFB, DE**

Parameter	Concentration (mg/L)				
	Effluent #1	Effluent #2	OWS #1	Pretreatment #1	Pretreatment #2
TPH	<1.0	<1.0	960	220	130
Benzene	<0.0010	<0.0010	2.1	1.7	1.7
Toluene	0.0028	0.0028	2.2	1.8	1.9
Ethylbenzene	<0.0010	<0.0010	1.0	0.81	0.93
Total Xylenes	0.0028	0.0026	5.2	4.0	4.6

Need to illustrate changes in influent concentrations over time. Supplemental fuel went from 7000 to 15000 units from day 1 to day 4

Table 9. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at Site SS27/XYZ, Dover AFB, DE

Parameter	Concentration (ppmv) Identity of hour of testing				
	ICE #1	ICE #2	SEAL GAS #1	SEAL GAS #2	ICE #3 - BLK
TPH as jet fuel	220	4.0	23,000	19,000	0.15
Benzene	1.9	0.0050	250	260	<0.0020
Toluene	2.1	0.0070	310	300	<0.0020
Ethylbenzene	0.45	0.0040	85	70	<0.0020
Xylenes	1.3	0.011	270	210	<0.0020
	27Aug95 1106	27Aug95 1111	27Aug95 1117	27Aug95 1126	29 Aug 95 0712

Table 10. BTEX Concentrations in LNAPL from Site SS27/XYZ, Dover AFB, DE

Check

Compound	Concentrations (mg/kg)
Benzene	1,300
Toluene	3,800
Ethylbenzene	4,000
Total Xylenes	19,000

Table 11. C-Range Compounds in LNAPL from Site SS27/XYZ, Dover AFB, DE

C-Range Compounds	Percentage of Total
<C9	45.5
C10	11.3
C11	12.4
C12	13.2
C13	10.9
C14	4.9
C15	1.9

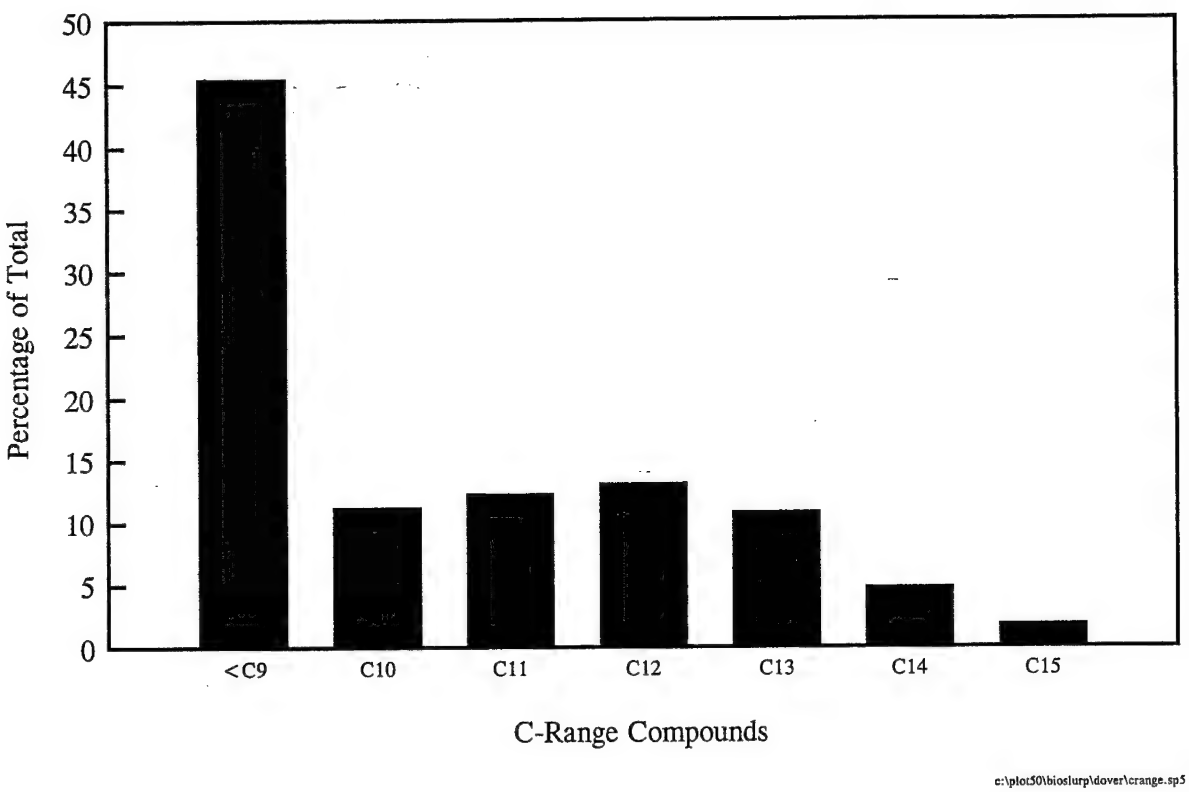

Figure 10. **Distribution of C-Range Compounds in Extracted LNAPL at Site SS27/XYZ, Dover AFB, DE**

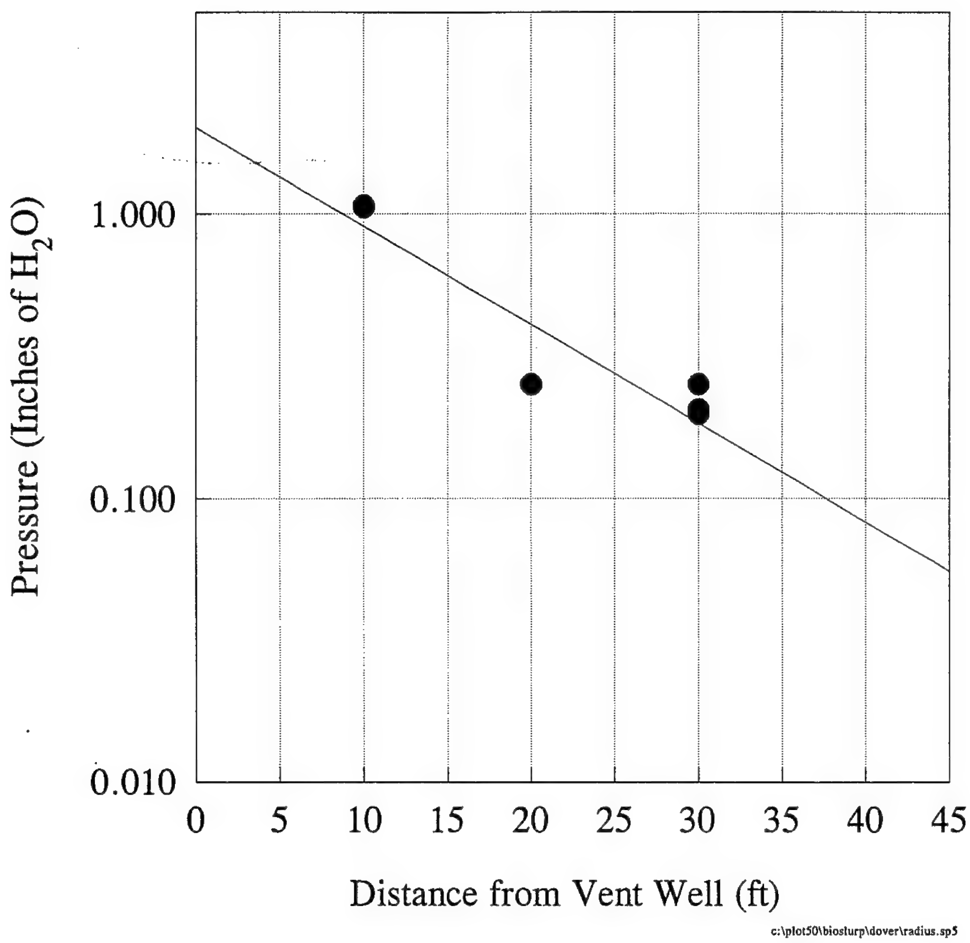

Figure 11. **Soil Gas Pressure Change as a Function of Distance During the Soil Gas Permeability Test**

4.5.2 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 12. Oxygen depletion was relatively rapid, with oxygen utilization rates ranging from 0.0013 to 0.48%O_2/hr. Biodegradation rates ranged from 0.021 to 7.8 mg/kg/day. The helium concentration was steady, indicating that leakage and diffusion were insignificant.

Table 12. In Situ Respiration Test Results at the Storage Tank 49 Site, Dover AFB

Monitoring Point	Oxygen Utilization Rate (%/hr)	Biodegradation Rate (mg/kg/day)
D-MPA-6.0′	0.0013	0.021
D-MPB-9.0′	0.23	3.8
D-MPC-6.0′	0.48	7.8
D-MPC-9.0′	0.28	4.6

5.0 DISCUSSION

Skimmer pumping was not as effective as bioslurping at recovering LNAPL from this site. Free product recovery rates decreased steadily during skimmer pumping, beginning at a rate of approximately 40 gallons/day during the initial skimmer pump test and decreasing to approximately 7 gallons/day by the end of the second skimmer pump test. In contrast, free product recovery rates during the bioslurper pump test remained relatively stable at approximately 45 gallons/day.

Groundwater recovery rates during the bioslurper pump test were high in comparison to rates during the skimmer pump tests. On average, groundwater was extracted at rates of 2,800 gallons/day during bioslurping and 400 gallons/day during skimming.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased significantly at all monitoring points (Table 7). Oxygen concentration at monitoring point D-MPB-

9.0′ did not change significantly during testing, which may be due to an area of low permeability. These results correlate with results from the soil gas permeability test.

Implementation of bioslurping at the Dover AFB test site probably would facilitate enhanced recovery of LNAPL from the water table and simultaneous in situ biodegradation of hydrocarbons in the vadose zone via bioventing. However, bioslurping will result in a vapor stream requiring treatment and the extraction of significant quantities of groundwater, which will increase cost. An economically viable method of treating the off-gas and the extracted water must be found before a long-term test is feasible.

6.0 REFERENCES

Battelle. 1995. *Test Plan and Technical Protocol for Bioslurping*, Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Rev. 2), Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc. for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Kittel, J.A., R.E. Hinchee, and M. Raj. 1994. *Full-Scale Startup of a Soil Venting-Based In Situ Bioremediation Field Pilot Study at Fallon NAS, Nevada*, Report prepared by Battelle Columbus Operations, for the Naval Facilities Engineering Services, Environmental Protection Division, Port Hueneme, CA.

APPENDIX A

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT DOVER AFB, DELAWARE

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT SITE SS27/XYZ, DOVER AFB, DELAWARE

FINAL

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
(AFCEE/ERT)
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AND

436 SPTG/CEVR
DOVER AFB, DELAWARE

2 AUGUST 1995

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT DOVER AIR FORCE BASE, DELAWARE (A003)
CONTRACT NO. F41624-94-C-8012

FINAL

to

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Air Force Center for Environmental Excellence
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436 SPTG/CEVR
Dover Air Force Base, Delaware

August 4, 1995

by

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AT DOVER AIR FORCE BASE, DELAWARE (A003)

DRAFT

to

Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
Brooks AFB, Texas 78235

August 3, 1995

1.0 INTRODUCTION

The U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division is conducting a nationwide application of an innovative technology for free-product recovery and soil bioremediation. The technology tested in the Bioslurper Initiative is vacuum-enhanced free-product recovery/bioremediation (bioslurping). The field test and evaluation are intended to demonstrate the feasibility of bioslurping by measuring system performance in the field. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as a light, nonaqueous phase liquid (LNAPL) recovery technology relative to conventional gravity-driven LNAPL recovery technologies. System performance parameters, mainly free-product recovery, will be determined at numerous sites. Field testing will be performed at many sites to determine the effects of different organic contaminant types and concentrations and different geologic conditions on bioslurping effectiveness. Figure 1 illustrates the locations of Bioslurper Initiative sites.

Plans for the field test activities are presented in two documents. The first is the overall Test Plan and Technical Protocol for the entire program entitled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall plan is supplemented by plans specific to each test site. The concise site-specific plans effectively communicate vapor and aqueous discharge rates to ensure compliance with regulatory requirements specific to the base.

The overall Test Plan and Technical Protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of site-specific Test Plan preparation and ensure consistent data collection across all test sites. The field program involves installation and operation of the bioslurping system supported by a wide variety of site characterization, performance monitoring, and chemical analysis activities. The basic methods to be applied from site to site do not change. Preparation and review of the overall Test Plan and Technical Protocol allow efficient documentation and review of the basic approach to the test program. Peer and regulatory review were performed for the overall Test Plan and Technical Protocol to ensure the credibility of the overall program.

This report is the site-specific Test Plan for application of bioslurping at Dover Air Force Base (AFB), Delaware. It was prepared based on site-specific information received by Battelle from Dover AFB and other pertinent site-specific information to support the overall Test Plan and Technical

Figure 1. Locations of Bioslurper Initiative Sites

Protocol. The initial review of data for site selection for the bioslurper test site was completed on Site SS27/XYZ.

2.0 SITE DESCRIPTION

Site SS27/XYZ is the Fuel Pump Station (Building 950) located near the northwest end of the northwest/southeast runway and the fueling pads, X, Y, and Z. Underground fuel lines connect the pump station to hydrants on the fueling pads. The pump station has primarily contained JP-4 jet fuel. Base personnel observed free product floating on water in manholes, which led to an initial site investigation.

Site SS27/XYZ contains a minimal amount of surface fill material over primarily fine to medium sand changing with depth to coarse/very coarse sand to a depth of 25 to 35 ft. Discontinuous lens of clay and of gravel also are present. Depths to groundwater range from approximately 10 to 12 ft below ground level (bgl).

Figure 2 shows the location of temporary monitoring wells at Site SS27/XYZ. Free product was detected in four temporary monitoring wells (Table 1). Figure 3 illustrates the locations of permanent monitoring wells and cone penetrometer test (CPT) points. Free product was detected at a thickness of 6.88 ft in monitoring well DM344 and was detected at CPT-15S and CPT-18S, although no measurement of thickness could be made. Based on these results, monitoring wells DM344 presents the greatest likelihood of being suitable as the bioslurper test well; however, all monitoring wells in the vicinity will be investigated for possible use in the short-term test.

Table 1. Free Product Thicknesses at Site SS27/XYZ, Dover AFB, DE

Location	Free Product Thickness (inches)
GP3003	4
GP3007	59
GP3008	38
GP3009	trace
DM 344	6.88 ft

A soil gas survey also was conducted at this site in 1989, results of which are shown in Figure 1. Concentrations up to 100,000 μg/L were found primarily around the fuel lines. Groundwater at this site has been found to be contaminated with petroleum hydrocarbons up to concentrations of 80,000 μg/L. Soil samples collected via cone penetrometer testing in 1995 have contained concentrations of BTEX ranging from 0.002 mg/kg up to 110 mg/kg and TPH concentrations of 0.1 to 1,100 mg/kg (Figure 4).

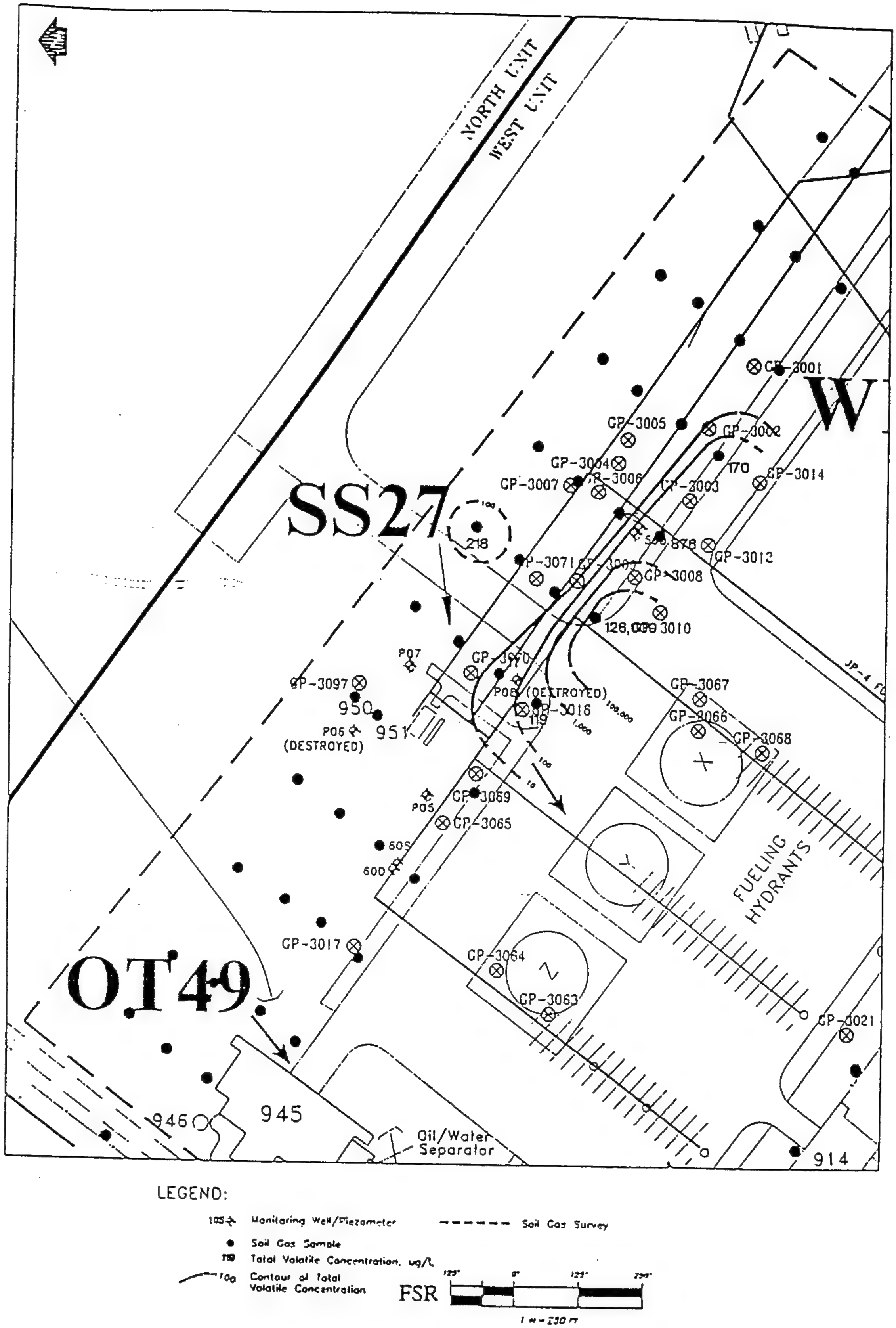
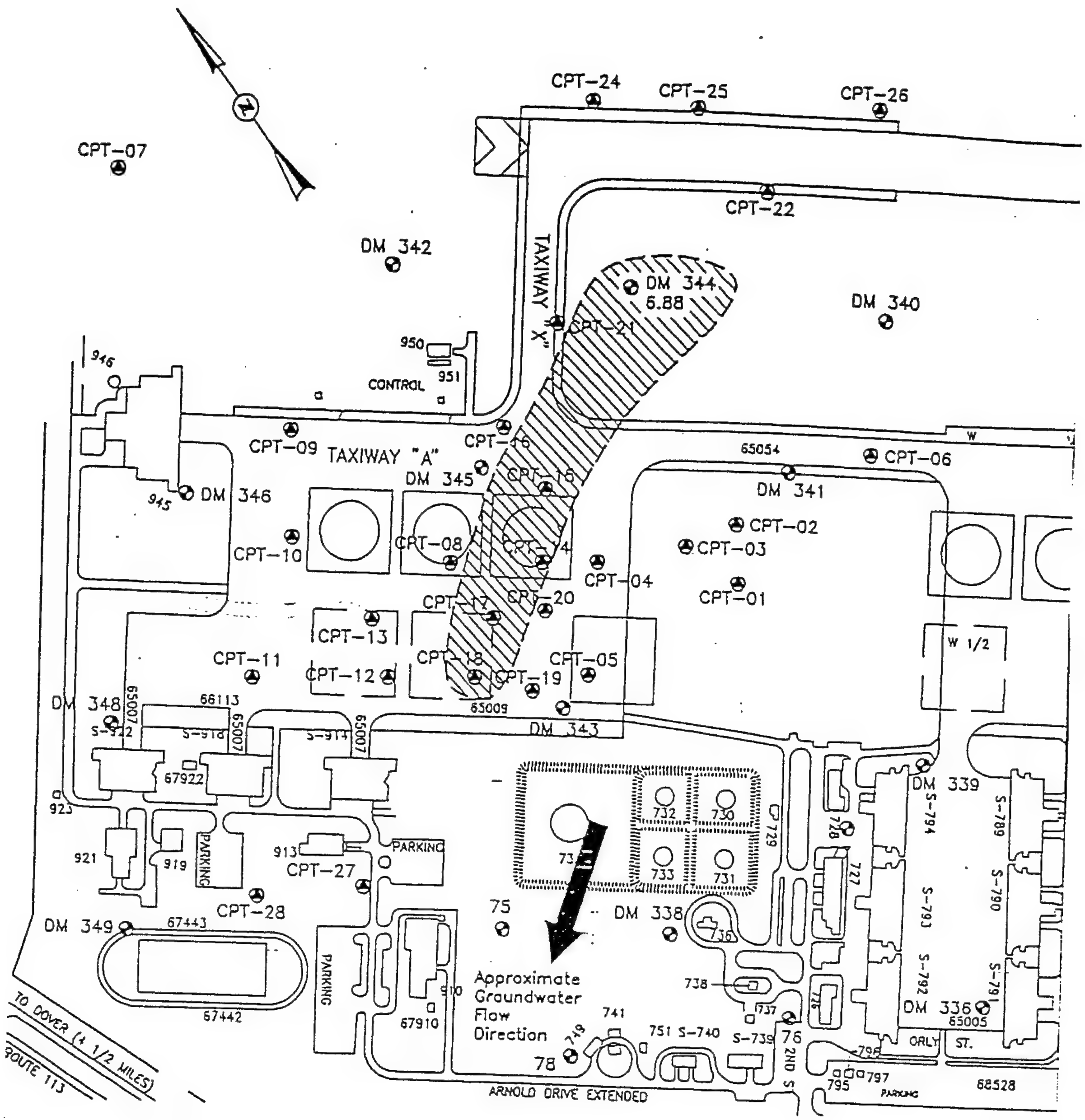


Figure 2. Location of Temporary Monitoring Wells and Results of a Soil Gas Survey at Site SS27/XYZ, Dover AFB, DE



400' 200' 0 400'

Approximate Scale in Feet

LEGEND

DM 341	Monitoring well.
CPT–01	Monitoring point and CPT test location installed by CPT rig.
6.88	Mobile LNAPL thickness (feet).
	Approximate extent of mobile LNAPL plume.
Note:	LNAPL was observed during sampling of CPT–15S and CPT–18S. Actual thickness could not be determined.

Figure 3. Locations of Permanent Groundwater Monitoring Wells and Cone Penetrometer Test Points at Site SS27/XYZ, Dover AFB, DE

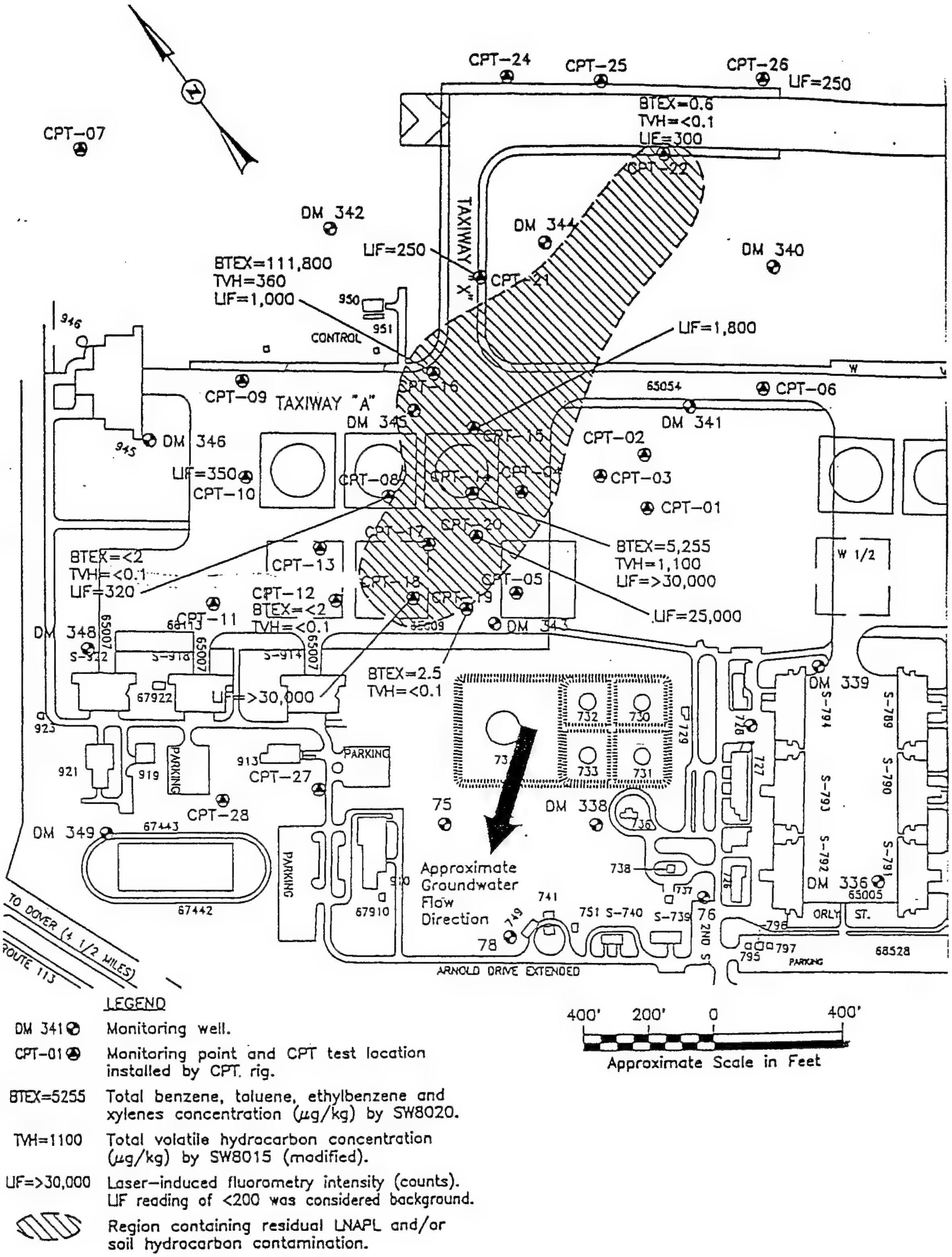


Figure 4. Soil Hydrocarbon Contamination as Indicated by Cone Penetrometer/Laser-Induced Fluorescence Sensor Results and Laboratory Analytical Results at Site SS27/XYZ, Dover AFB, DE

3.0 PROJECT ACTIVITIES

The field activities discussed in the following sections are planned for the bioslurper pilot test at Dover AFB. Additional details about the activities are presented in the overall Test Plan and Technical Protocol. As appropriate, specific sections in the overall Test Plan and Technical Protocol are referenced. Table 2 presents the schedule of activities for the Bioslurper Initiative at Dover AFB.

Table 2. Schedule of Bioslurper Pilot Test Activities

Pilot Test Activity	Schedule
Mobilization	Day 1-2
Site Characterization	Day 2-3
LNAPL/Groundwater Interface Monitoring and Baildown Tests	
Soil Gas Survey (Limited)	
Monitoring Point Installation (3 monitoring points)	
Soil Sampling (BTEX, TPH, physical characteristics)	
System Installation	Day 2-3
Test Startup	Day 3
Skimmer Pump Test (2 days)	Day 3-4
Bioslurper Pump Test (4 days)	Day 6-9
Soil-Gas Permeability Testing	Day 6
Skimmer Pump Test (continued)	Day 10
In Situ Respiration Test - Air/Helium Injection	Day 10
In Situ Respiration Test - Monitoring	Day 11-16
Drawdown Pump Test (2 days)	Day 11-12
Demobilization/Mobilization	Day 13-14

3.1 Mobilization to the Site

After the site-specific Test Plan is approved, Battelle staff will mobilized equipment to the site. Some of the equipment will be shipped via air express to Dover AFB prior to staff arrival. The Base Point-of-Contact (POC) will have been asked in advance to find a suitable holding facility to receive the bioslurper pilot test equipment so that it will be easily accessible to the Battelle staff when they arrive with the remainder of the equipment. The exact mobilization date will be confirmed with the Base POC as far in advance of fieldwork as is possible. The Battelle POC will provide the Base POC with

information on each Battelle employee who will be on site. Battelle personnel will be mobilized to the site after confirmation that the shipped equipment has been received by Dover AFB.

3.2 Site Characterization Tests

3.2.1 Baildown Tests

The baildown test is the primary test for selection of the bioslurper test well. Baildown tests will be performed at wells that contain measurable thicknesses of LNAPL to estimate the LNAPL recovery potential at those particular wells. In most cases, the well exhibiting the highest rate of LNAPL recovery will be selected for the bioslurper extraction well. A sample of free LNAPL will be collected at this point for analyses of boiling point distribution and BTEX concentration. Detailed procedures for the baildown tests are provided in Section 5.6 of the overall Test Plan and Technical Protocol.

3.2.2 Soil-Gas Survey (Limited)

A small-scale soil gas survey will be conducted to identify the best location for installation of the bioslurping system. The soil gas survey will be conducted in areas where historical site data indicated the highest contamination levels. These areas will be surveyed to select the locations for installation of soil gas monitoring points. Monitoring points will be located in areas that exhibit the following soil gas characteristics.

1. Relatively high TPH concentrations (10,000 ppmv or greater).

2. Relatively low oxygen concentrations (between 0% and 2%).

3. Relatively high carbon dioxide concentrations (depending on soil type, between 2% and 10% or greater).

Additional information on the soil gas survey is provided in Section 5.2 of the overall Test Plan and Technical Protocol.

3.2.3 Monitoring Point Installation

Monitoring points must be installed to determine the radius of influence of the bioslurper system in the vadose zone. A general arrangement of the bioslurping well and monitoring points is shown in Figure 3.

Upon completion of the initial soil gas survey and baildown tests, at least three soil gas monitoring points will be installed (unless existing monitoring points are available for use) to measure soil gas changes that occur during bioslurper operation. These monitoring points should be located in highly contaminated soils within the free-phase plume and should be positioned to allow detailed monitoring of the in situ changes in soil gas composition caused by the bioslurper system. A schematic diagram of a typical monitoring point is shown in Figure 4. Information on monitoring point installation can be found in Section 4.2.1 of the overall Test Plan and Technical Protocol.

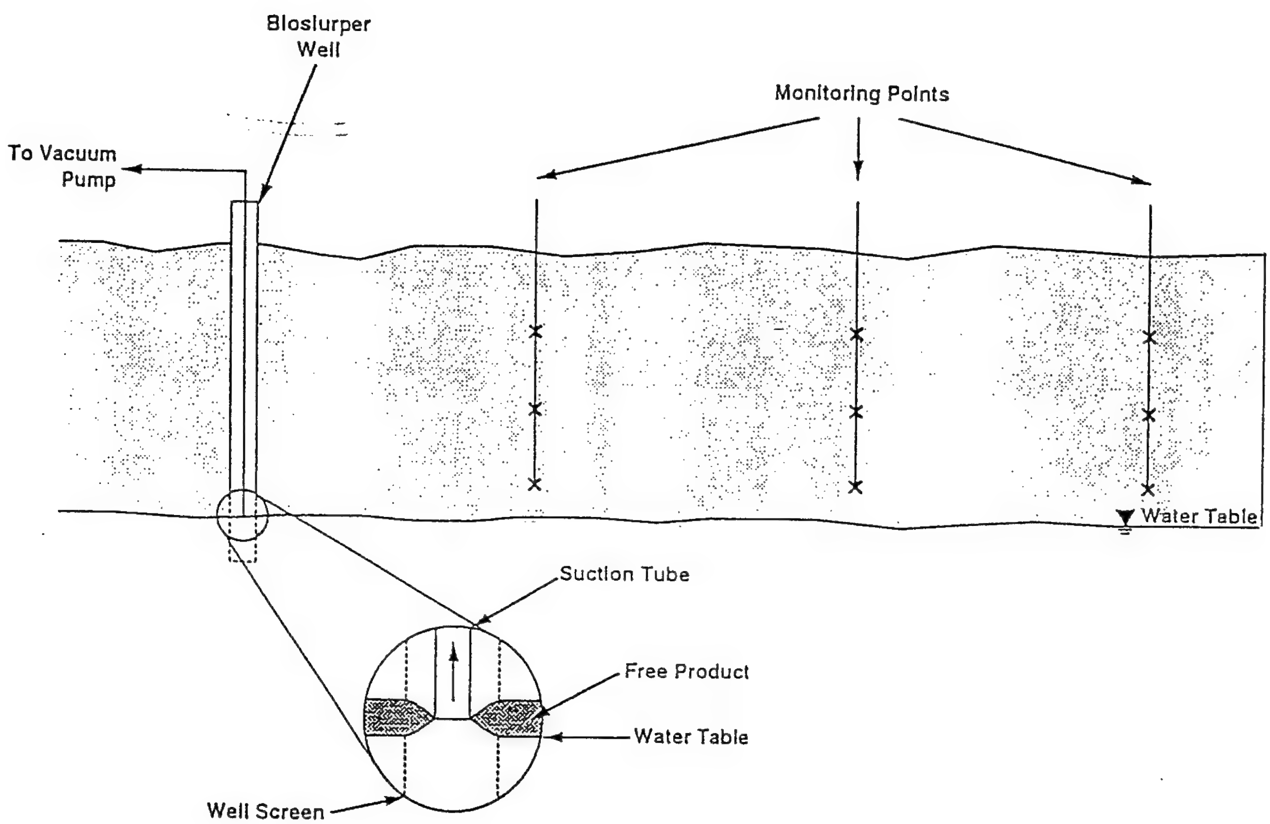


Figure 5. General Bioslurper Well and Monitoring Point Arrangement

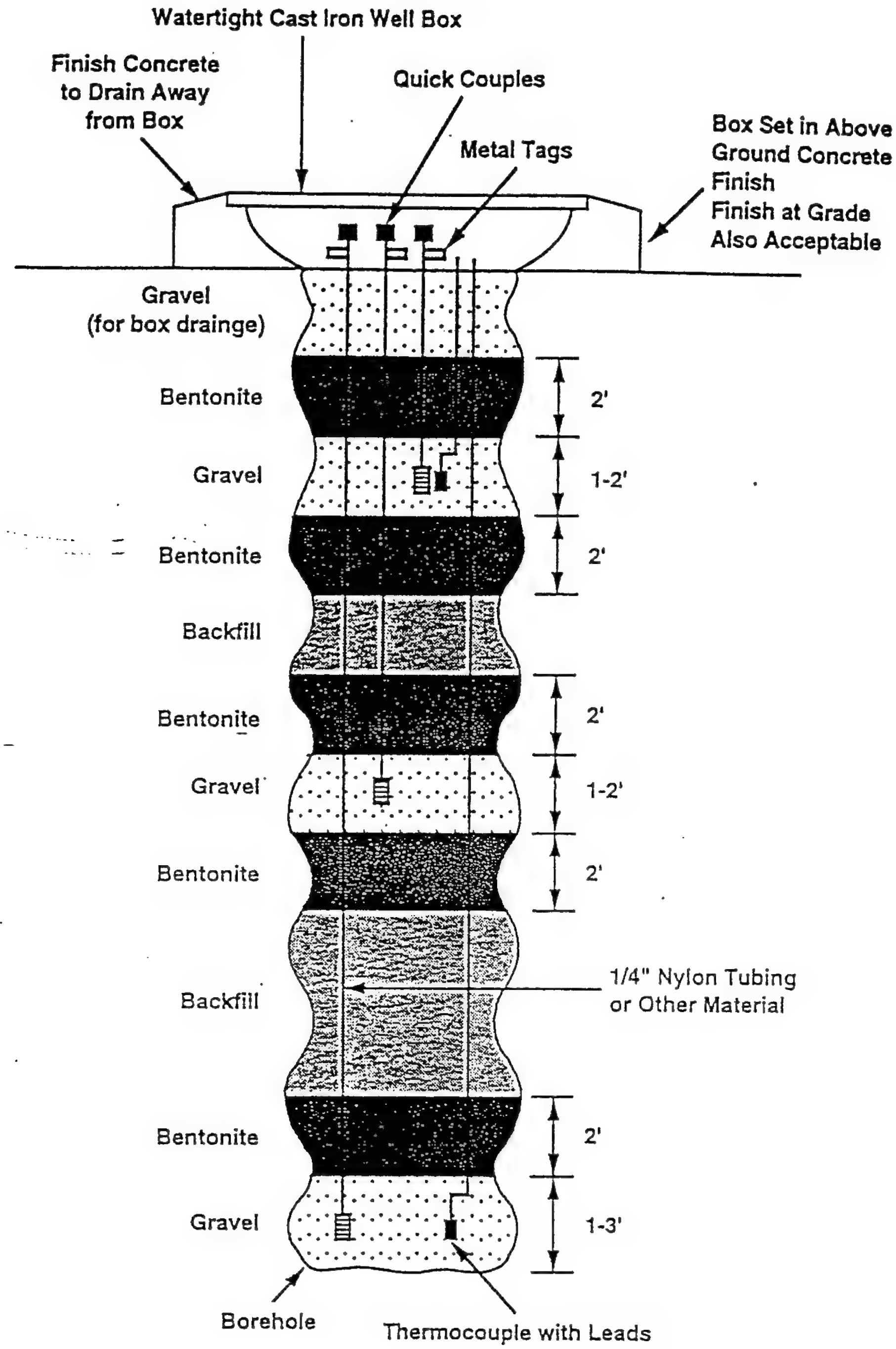


Figure 6. Schematic Diagram of a Typical Monitoring Point

3.2.4 Soil Sampling

Soil samples will be collected from each boring to determine the physical and chemical composition o the soil near the bioslurper test site. Soil samples will be collected from the boreholes advanced for monitoring point installation at two or three locations at the site chosen for the bioslurper test. Generally, samples will be collected from the capillary fringe over the free product.

Soil samples from each boring will be analyzed for BTEX, bulk density, moisture content, particle size distribution, porosity, and TPH. Section 5.5.1 of the overall Test Plan and Technical Protocol contains additional information on field measurements and sample collection procedures for soil sampling.

3.3 Bioslurper System Installation and Operation

Once the well to be used for the bioslurper test installation at Dover AFB has been identified, the bioslurper pump and support equipment will be installed and pilot testing will be initiated.

3.3.1 System Setup

After the preliminary site characterization has been completed and the bioslurper candidate well has been selected, the shipped equipment will be mobilized from the holding facility to the test site, and the bioslurper system will be assembled. Figure 7 shows a flow diagram of the bioslurper process.

Before the LNAPL recovery tests are initiated, all relevant baseline field data will be collected and recorded. These data will include soil gas concentrations, initial soil gas pressures, the depth to groundwater, and the LNAPL thickness. Ambient soil and all atmospheric conditions (e.g., temperature, barometric pressure) also will be recorded. All emergency equipment (i.e., emergency shutoff switches and fire extinguishers) will be installed and checked for proper operation at this time.

A clear, level 20- by 10-ft area near the well selected for the bioslurper test installation will be identified to station the equipment required for bioslurper system operation. Additional information on bioslurper system installation is provided in Section 6.0 of the overall Test Plan and Technical Protocol.

3.3.2 System Shakedown

A brief startup test will be conducted to ensure that the system is constructed properly and operates safely. All system components will be checked for problems and/or malfunctions. A checklist will be provided to document the system shakedown.

3.3.3 System Startup and Test Operations

After installation is complete and the bioslurper system is confirmed to be operating properly, the LNAPL recovery tests will be started. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as an LNAPL recovery test technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative includes three separate LNAPL recovery tests: (1) a skimmer pump test, (2) a bioslurper pump test, and (3) a drawdown pump test. Figures 8 through 10 illustrate typical well construction details and the slurper tube and valve position

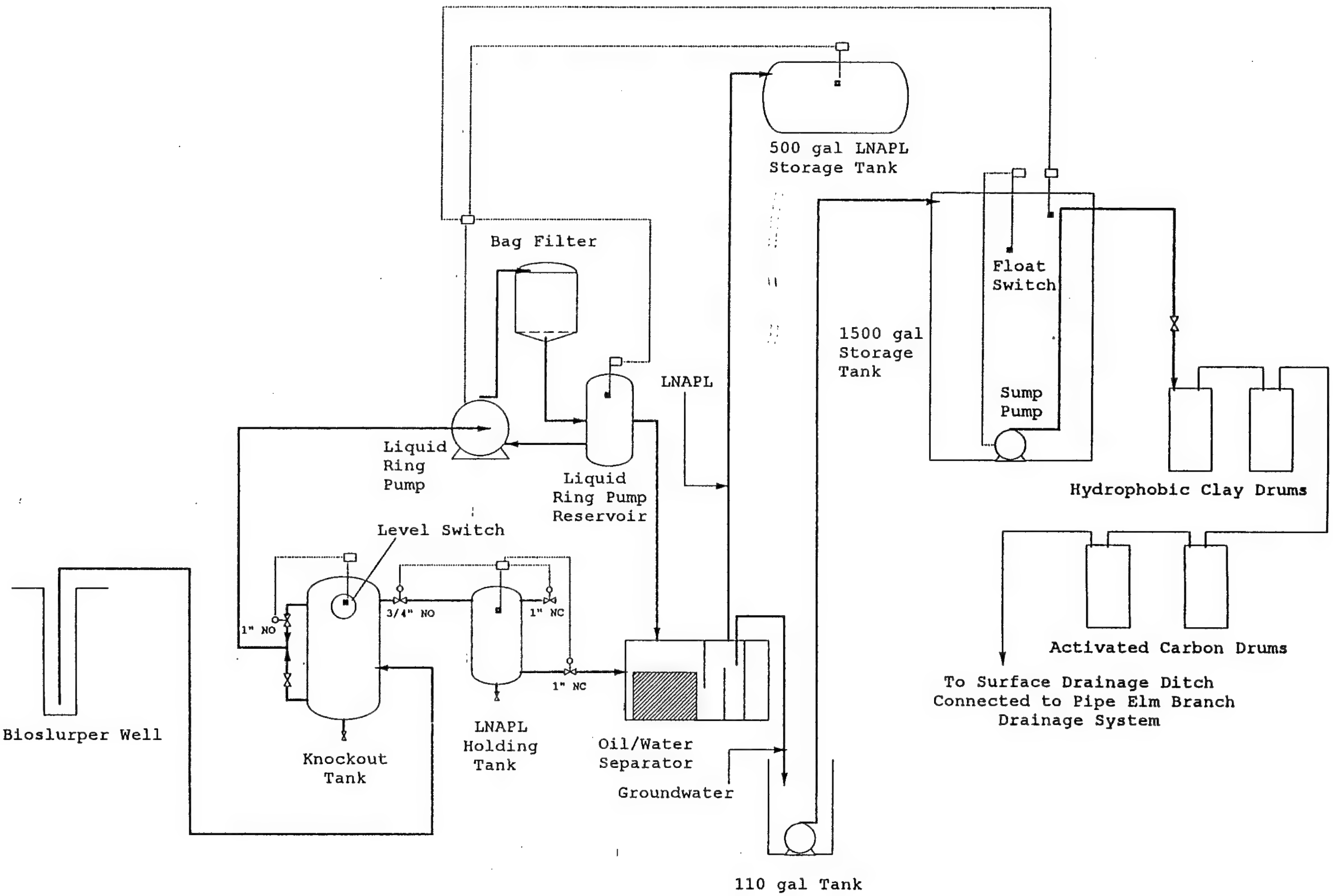


Figure 7. Bioslurper Process Flow at Site SS27/XYZ, Dover AFB, DE

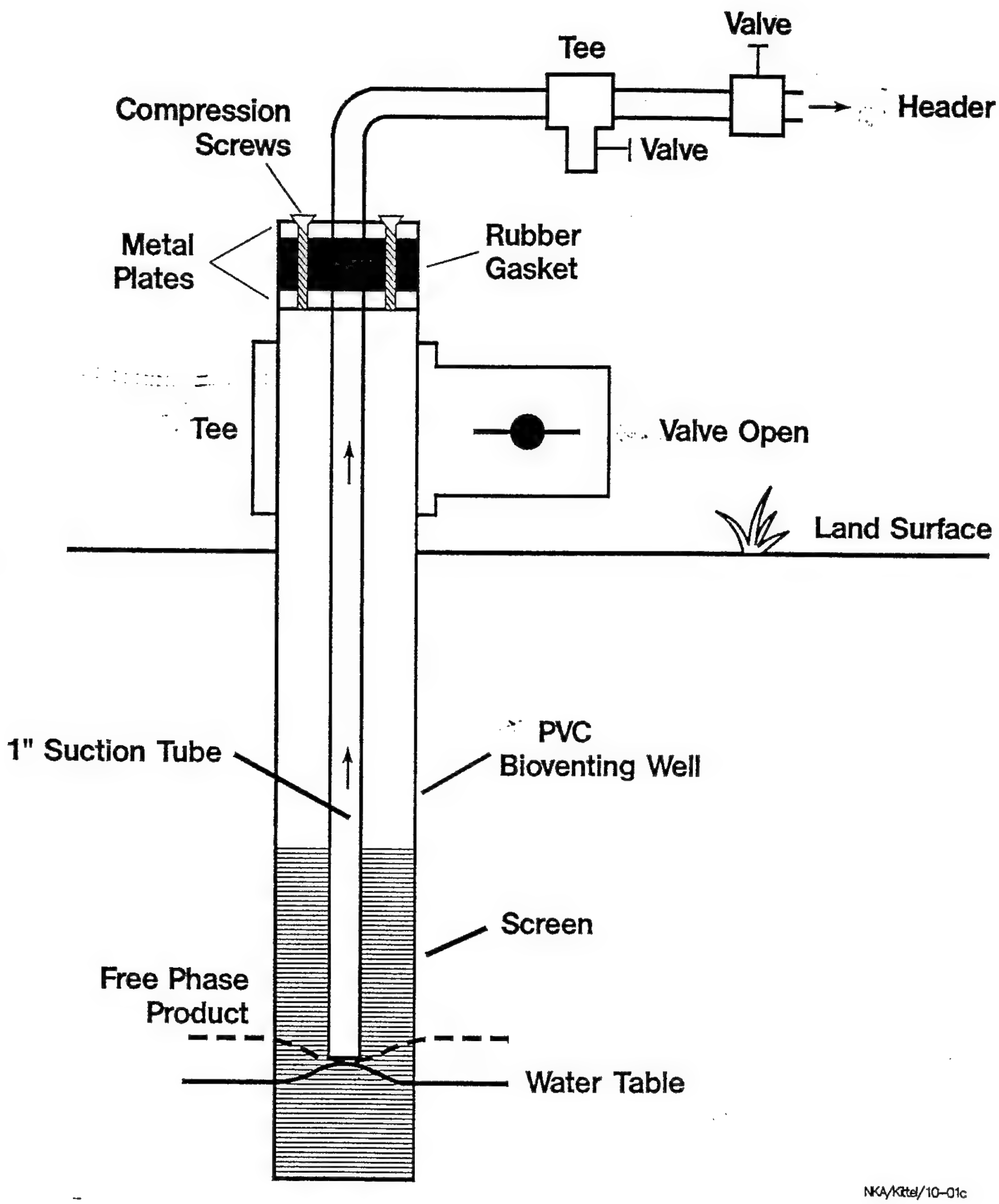


Figure 8. Schematic Diagram Illustrating Slurper Tube Placement and Valve Position for the Skimmer Pump Test

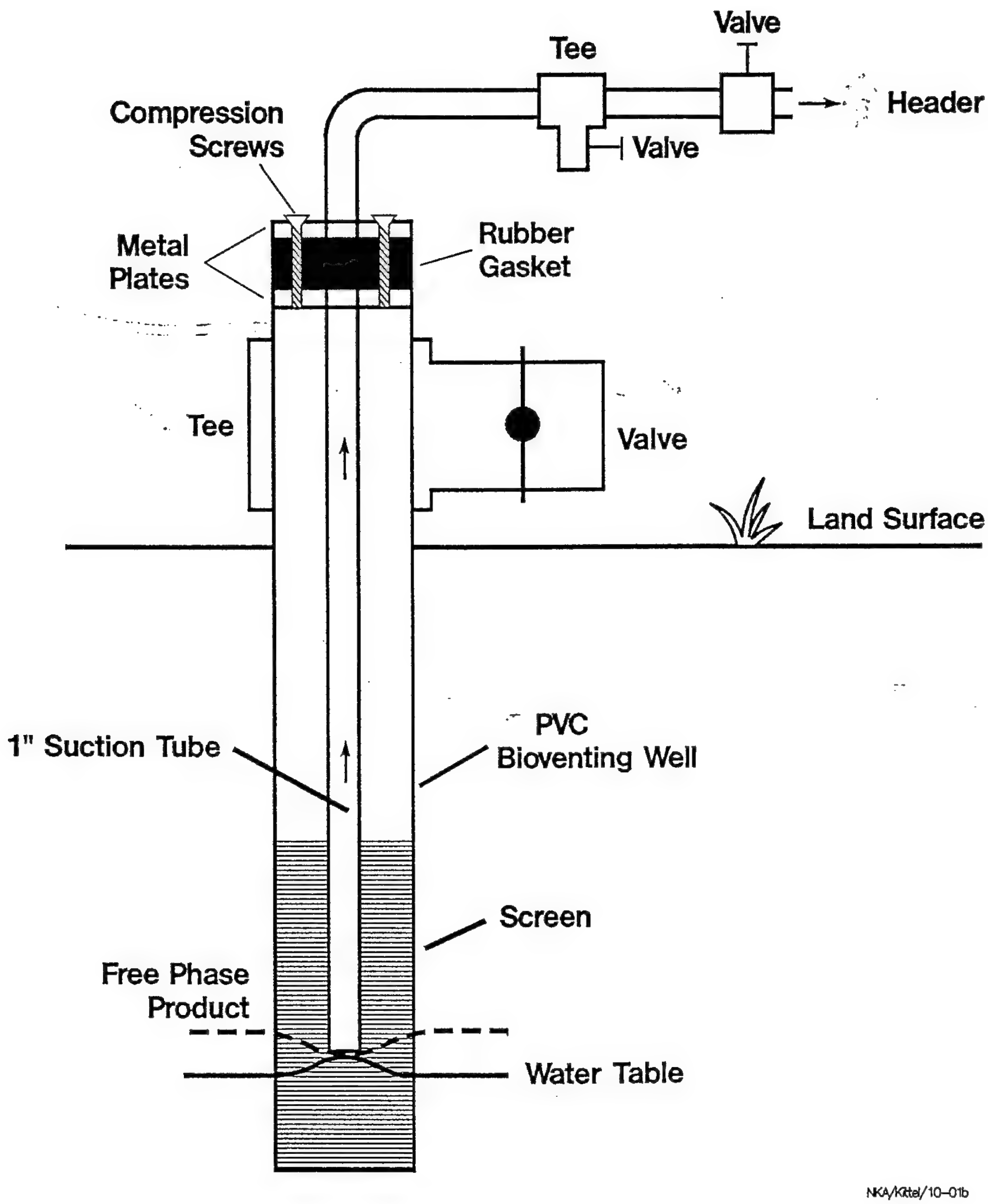


Figure 9. Schematic Diagram Illustrating Slurper Tube Placement and Valve Position for the Bioslurper Pump Test

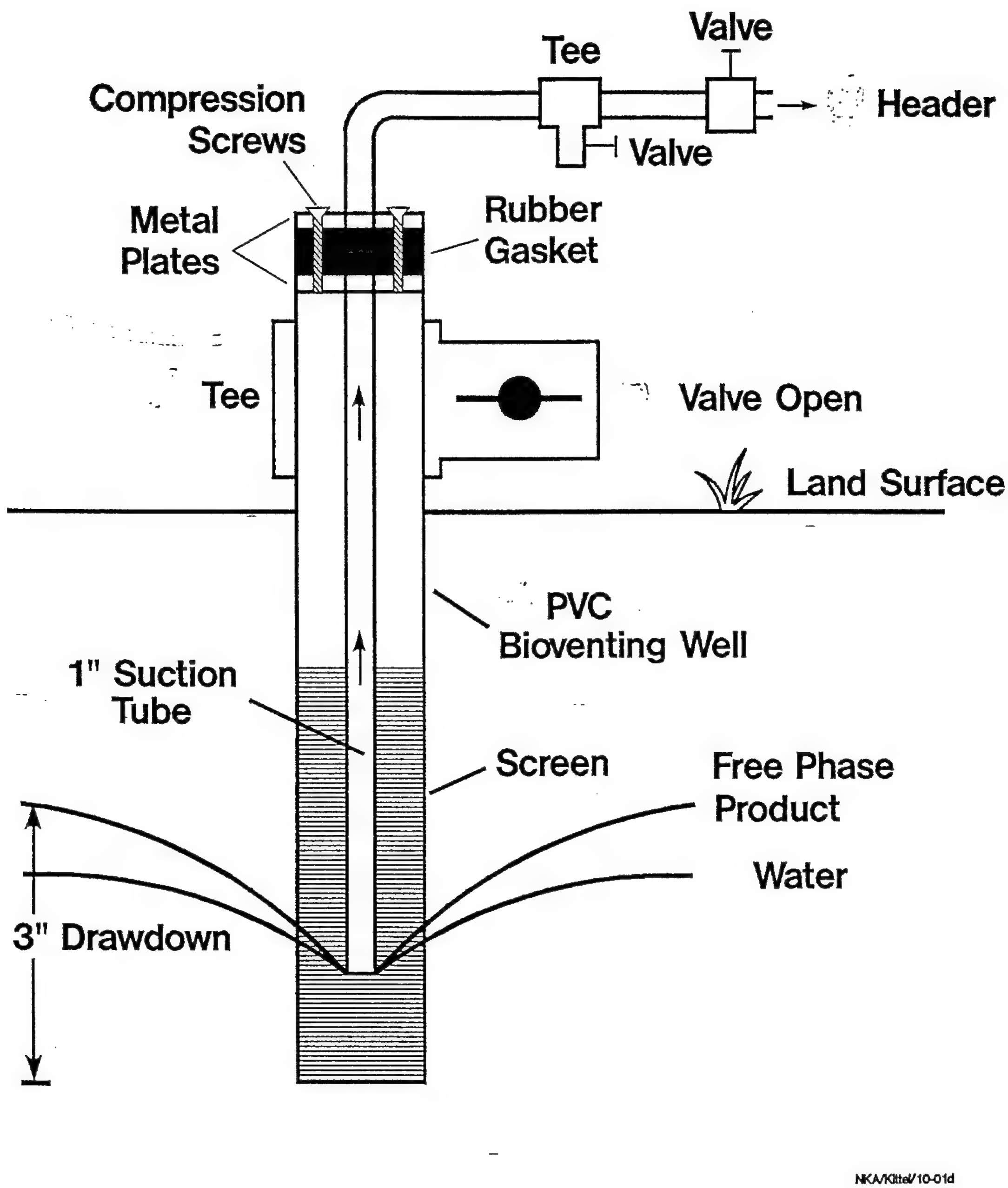


Figure 10. Schematic Diagram Illustrating Slurper Tube Placement and Valve Position for the Drawdown Pump Test

for operation in either the skimmer, bioslurper, or drawdown configuration, respectively. The three recovery tests are described in detail in Section 7.3 of the overall Test Plan and Technical Protocol.

The bioslurper system operating parameters that will be measured during operation are vapor discharge, aqueous effluent, LNAPL recovery volume rates, vapor discharge volume rates, and groundwater discharge volume rates. Vapor monitoring will consist of periodic monitoring of TPH using hand-held instruments supplemented by two samples collected for detailed laboratory analysis. Two samples of aqueous effluent will be collected for analysis of BTEX and TPH. Recovered LNAPL volume will be recorded using an in-line flow-totalizing meter. The off-gas discharge volume will be measured using a calibrated pitot tube, and the groundwater discharge volume will be recorded using an in-line flow-totalizing meter. Section 8.0 of the overall Test Plan and Technical Protocol describes process monitoring of the bioslurper system.

3.3.4 Soil Gas Profile/Oxygen Radius of Influence Test

Changes in soil gas profiles will be measured before and during the bioslurper pump test. Soil gas will be monitored for concentrations of oxygen, carbon dioxide, and TPH using field instruments. These measurements will be used to determine the oxygen radius of influence of the bioslurper.

3.3.5 Soil Gas Permeability Tests

A soil gas permeability test will be conducted concurrently with startup of the bioslurper pump test. Soil gas permeability data will support the process of estimating the vadose zone radius of influence of the bioslurper system. Soil gas permeability results also will aid in determining the number of wells required if it is decided to treat the site with a full-scale bioslurper system. The soil gas permeability test method is described in Section 5.7 of the overall Test Plan and Technical Protocol.

3.3.6 LNAPL and Groundwater Level Monitoring

During the bioslurper pump test, the LNAPL and groundwater levels will be monitored in a well adjacent to the extraction well if such a well exists. The top of the monitoring well will be sealed from the atmosphere so the subsurface vacuum will be contained (Figure 11). Additional information for the monitoring of fluid levels is provided in Section 4.3.4 of the overall Test Plan and Technical Protocol.

3.3.7 In Situ Respiration Test

An in situ respiration test will be conducted after completion of the bioslurper pilot tests. The in situ respiration test will involve injection of air and helium into selected soil gas monitoring points followed by monitoring changes in concentrations of oxygen, carbon dioxide, TPH, and helium in soil gas at the injection point. Measurement of the soil gas composition typically will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours for about 2 days. Timing of the tests will be adjusted based on the oxygen-use rate. If oxygen depletion occurs rapidly, more frequent monitoring will be required. If oxygen depletion is slow, less frequent readings will be acceptable. The oxygen utilization rate will be used to estimate the biodegradation rate at the site. Further information on the procedures and data collection of the in situ respiration test is provided in Section 5.8 of the overall Test Plan and Technical Protocol.

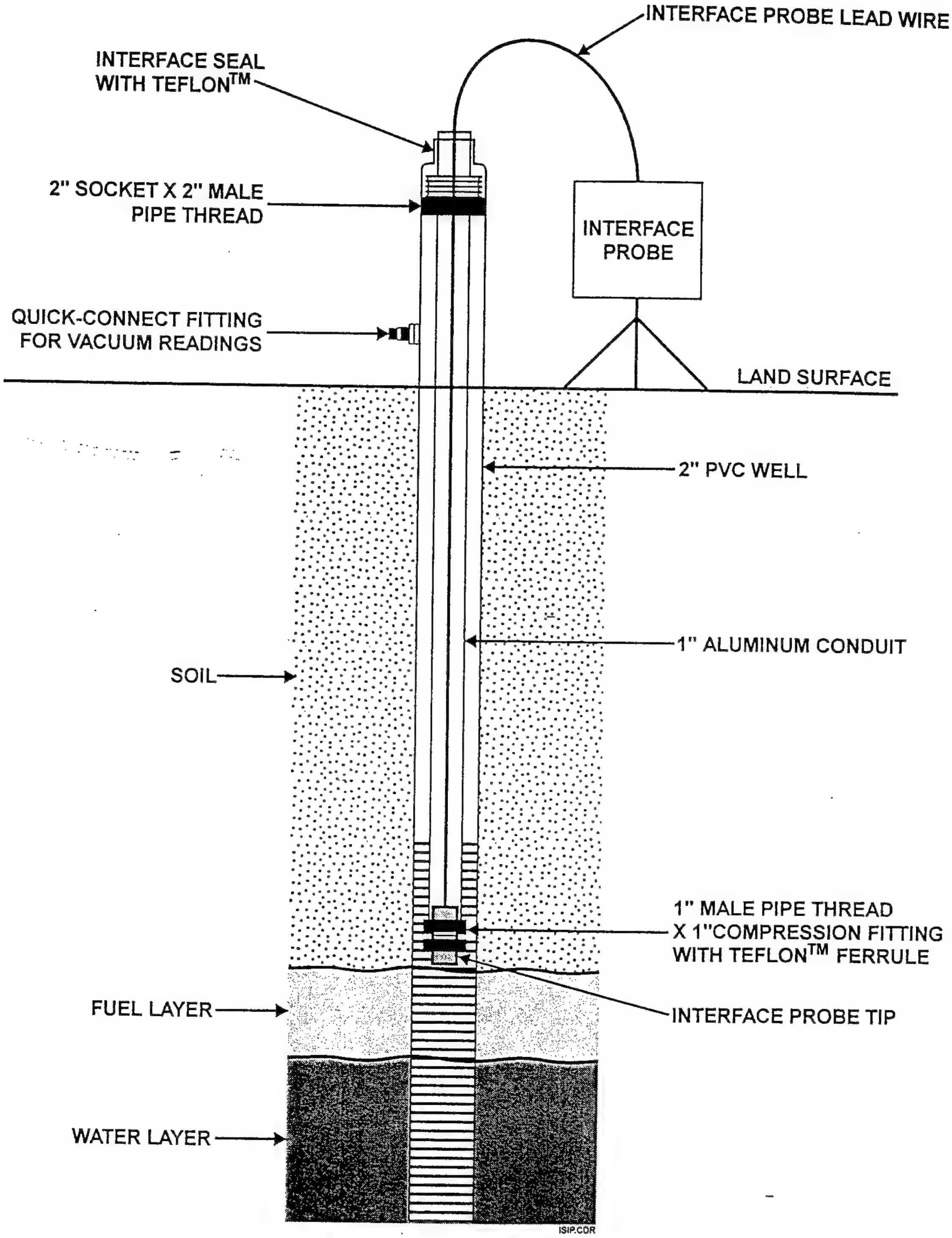


Figure 11. Schematic Diagram of Sealed Interface Probe for Measuring Fuel and Water Levels During the Bioslurper Pump Test

3.4 Demobilization

Once all necessary tests have been completed at the Dover AFB site, the equipment will be disassembled by Battelle staff. The equipment then will be moved back to the holding facility, where it will remain until its next destination is determined. Battelle staff will receive this information and will be responsible for shipment of the equipment to the next site before they leave Dover AFB.

4.0 BIOSLURPER SYSTEM DISCHARGE

4.1 Vapor Discharge Disposition

Battelle expects that the operation of the bioslurper test system at Dover AFB will require a waiver or a point source air release registration and may require some additional permits. However, because of the short duration of the bioslurper pilot test, it can be assumed that the concentrations of TPH released to the atmosphere will be approximately 65 lb/day and benzene will be <1.0 lb/day without treatment. This value is based on the average discharge rates at two bioslurper test sites (Travis AFB and Wright-Patterson AFB) that are contaminated with a similar type of fuel as that found at Site SS27/XYZ. The discharge value may vary depending on concentrations in soil gas and the permeability of the soil. The data for benzene and TPH discharge levels for five previous bioslurper sites are presented in Table 3.

Vapor discharge will be treated through an internal combustion engine (ICE). The ICE is subject to a categorical permitting exclusion and is the best available technology for treatment of hydrocarbon vapors. The ICE is capable of >99% destruction of hydrocarbon vapors; therefore, given this treatment efficiency, vapor emissions at this site after treatment with the ICE would be <1.0 lb/day TPH and <0.01 lb/day benzene. A cost and performance document on the ICE is provided in Appendix A.

Table 3. Benzene and TPH Vapor Discharge Levels at Previous Bioslurper Test Sites

Site Location	Fuel Type	Extraction Rate (scfm)	Benzene (ppmv)	TPH (ppmv)	Benzene Discharge (lb/day)	TPH Discharge (lb/day)
Andrews AFB	No. 2 Fuel Oil	8.0	16	2,000	0.0010	0.20
Site 1, Bolling AFB	No. 2 Fuel Oil	4.0	0.20	153	0.00030	0.0090
Site 2, Bolling AFB	Gasoline	21	370	70,000	2.3	470
Johnston Atoll	Jet Fuel	10	0.60	975	0.0017	5.7
Travis AFB	Jet Fuel	20	100	10,800	0.58	130
Wright-Patterson AFB	Jet Fuel	3.0	ND	595	0	1.0

ND = Not detected.

To ensure the safety and regulatory compliance of the bioslurper system, field soil gas screening instruments will be used to monitor vapor discharge concentration. The volume of vapor discharge will be monitored daily using air flow instruments. If state regulatory requirements will not permit the expected amount of organic vapor discharge to the atmosphere, the Base POC should inform AFCEE and Battelle so that alternative plans can be made prior to mobilization to the site. Table 4 presents information typically required to complete an air release registration form.

Table 4. Air Release Summary Information

Data Item	Air Release Information
Contractor Point-of-Contact	Jeff Kittel, (614) 424-6122
Contractor address	Battelle, 505 King Avenue, Columbus, OH 43201
Estimated total quantity of petroleum product to be recovered	To be determined
Description of petroleum product to be recovered	JP-4 jet fuel
Planned date of test start	To be determined
Test duration	9-10 days (active pumping)
Maximum expected volatile organic compound level in air	~65 lb/day TPH, <1.0 lb/day benzene
Stack height above ground level	10 ft

4.2 Aqueous Influent/Effluent Disposition

The flowrate of groundwater pumped by the bioslurper will be less than 5 gpm. However, it may be necessary in Delaware to obtain a groundwater pumping waiver or registration permit. If one is required, the Base POC will inform Battelle of the necessary steps in obtaining the waiver or permit.

Operation of the bioslurper system will generate an aqueous waste discharge that will be passed through a bag filter, an oil/water separator, hydrophobic clay drums, and activated carbon drums (Figure 7). Table 5 provides effluent data for sites where groundwater has been treated in this manner. Sites not listed did not receive any treatment other than an oil/water separator. The intention of Battelle staff will be to dispose of the treated wastewater by discharge directly to the on-site surface drainage ditch connected to the Pipe Elm Branch drainage system. Compliance monitoring will be conducted at Compliance Monitoring Point 3 (Figure 12) to ensure compliance with existing regulations.

4.3 Free-Product Recovery Disposition

The bioslurper system will recover free-phase product from the pilot tests performed at Dover AFB. Recovered free product will be turned over to the Base for disposal and/or recycling. The volume of free product recovered from the Base will not be known until the tests have been performed. The maximum recovery rate for this system is 5 gpm, but the actual rate of LNAPL recovery likely will be much lower.

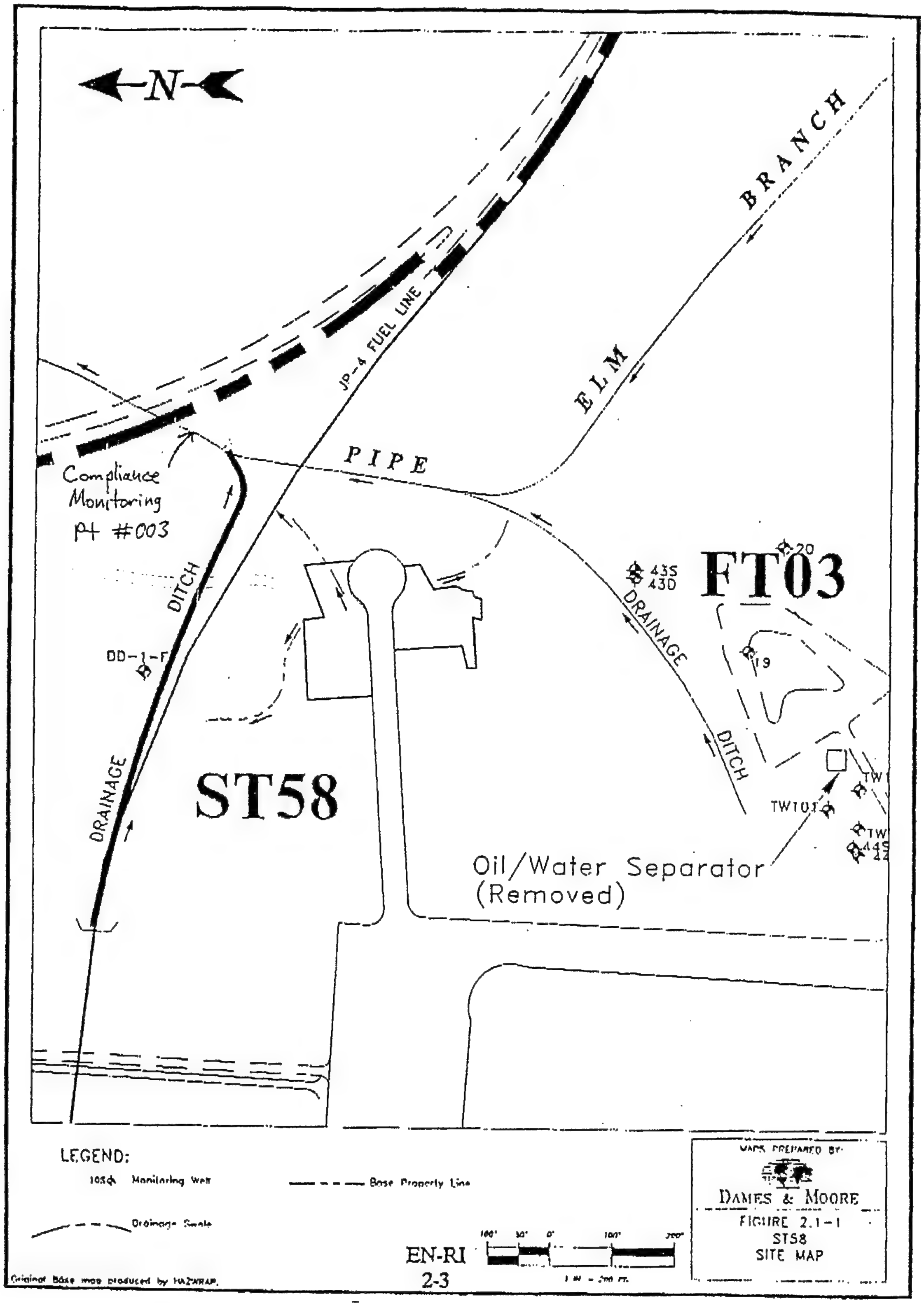


Figure 12. Location of Compliance Monitoring Point 3, Dover AFB, DE

Table 5. **Effluent Groundwater Concentrations of Benzene and TPH After Treatment at Previous Bioslurper Test Sites[1]**

Site Location	Fuel Type	Benzene (mg/L)	TPH (mg/L)
Andrews AFB	No. 2 Fuel Oil	0.096	270
Travis AFB	Jet Fuel	1.0	17

1 Groundwater effluent at Bolling AFB, Johnston Atoll, and Wright-Patterson AFB were discharged with less treatment, and are therefore not presented in this table.

5.0 SCHEDULE

The schedule for the bioslurper fieldwork at Dover AFB will depend on approval of the project Test Plan. Battelle will determine a definitive schedule as soon as possible after approval is received. Battelle will have two to three staff members on site for approximately 2 weeks to conduct all necessary pilot testing. At the conclusion of the field testing at Dover AFB, all staff will return their Base passes. Battelle staff will remove all bioslurper field testing equipment from the Base before they leave the site.

6.0 PROJECT SUPPORT ROLES

This section outlines some of the major functions of personnel from Battelle, Dover AFB, and AFCEE during the bioslurper field test.

6.1 Battelle Activities

The obligations of Battelle in the Bioslurper Initiative at Dover AFB will be to supply the staff and equipment necessary to perform all the tests on the bioslurper system. Battelle also will provide technical support in the areas of water and vapor discharge permitting, digging permits, staff support during the extended testing period, and any other technical areas that need to be addressed.

6.2 Dover AFB Support Activities

To support the necessary field tests at Dover AFB, the Base must be able to provide the following:

a. Any digging permits and utility clearances that need to be obtained prior to the initiation of the fieldwork. Any underground utilities should be clearly marked to reduce the chance of utility damage and/or personal injury during soil gas probe and possible well installation. Battelle will not begin field operations without these clearances and permits.

b. The Air Force will be responsible for obtaining Base and site clearance for the Battelle staff that will be working at the Base. The Base POC will be furnished with all necessary information on each staff member at least one week prior to field startup. We have been informed that this site is a controlled area subject to more stringent security requirements; therefore, the Base will be responsible for ensuring that these security requirements are met.

c. Access to the on-site surface drainage ditch connected to the Pipe Elm Branch drainage system must be furnished so that Battelle staff can discharge the bioslurper aqueous effluent directly to the drainage ditch.

d. Regulatory approval, if required, must be obtained by the Base POC prior to startup of the bioslurper pilot test. As stated previously, it is likely that a waiver or permit to allow air releases or a point source air release registration will be required for emissions of approximately 65 lb/day of TPH and <1.0 lb/day benzene without treatment. A waiver for pumping and discharging groundwater at a rate of 5 gpm may be required. The Base POC will obtain all necessary Base permits prior to mobilization to the site. Battelle will provide technical assistance in preparing regulatory approval documents.

e. The Base also will be responsible for the disposition of all waste generated from the pilot testing. Such waste includes any soil cuttings generated from drilling, and all aqueous wastestreams produced from the bioslurper tests. All free product recovered from the bioslurper operation will be disposed of or recycled by the Base. Battelle will provide technical assistance in disposing of the waste generated from the bioslurper pilot test.

f. Before field activities begin, the Health and Safety Plan will be finalized with information provided by the Base POC. Table 6 is a checklist for the information required to complete the Health and Safety Plan. All emergency information will be obtained by the Site Health and Safety office before operations begin.

6.3 AFCEE Activities

The AFCEE POC will act as a liaison between Battelle and Dover AFB staff. The AFCEE POC will ensure that all necessary permits are obtained and the space required to house the bioslurper field equipment is found.

The following is a listing of Battelle, AFCEE, and Dover AFB staff who can be contacted in case of emergency and/or for required technical support during the Bioslurper Initiative tests at Dover AFB.

Table 6. Health and Safety Information Checklist

Emergency Contacts		Name	Telephone Number
Hospital:	Dover AFB		(302) 677-2600
	Kent General Hospital		(302) 734-4700
Fire Department		Emergency Switchboard	(302) 677-2117
Ambulance and Paramedics		Emergency Switchboard	(302) 677-2118
Police Department		Emergency Switchboard	(302) 677-6664
Explosives Unit			
EPA Emergency Response Team		Switchboard	(908) 321-6660
Other			
Program Contacts			
Air Force		Patrick Haas	(210) 536-4314
Battelle		Jeff Kittel	(614)424-6122
		Eric Drescher	(614) 424-3088
Dover AFB		Mick Mikula	(302) 677-6845
Other			
Emergency Routes			
Hospital (maps attached)			
Other			

Battelle POCs	Jeff Kittel	(614) 424-6122
	Eric Drescher	(614) 424-3088
AFCEE POC	Patrick Haas	(210) 536-4314
Dover AFB POC	Mick Mikula	(302) 677-6845
Regulatory POCs		
Delaware UST Branch	Frank Gavas	(302) 323-4588
U.S. EPA Region 3	Nicholos DiNardo	(215) 597-7858

7.0 REFERENCE

Battelle. 1995. *Test Plan and Technical Protocol for Bioslurping*. Prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

APPENDIX A

COST AND PERFORMANCE DOCUMENT ON INTERNAL COMBUSTION ENGINES

A PERFORMANCE AND COST EVALUATION OF INTERNAL COMBUSTION ENGINES FOR THE DESTRUCTION OF HYDROCARBON VAPORS FROM FUEL-CONTAMINATED SOILS

AUGUST 1994

Distribution is unlimited; approved for public release

ENVIRONMENTAL SERVICES OFFICE
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)

SECTION 1

INTRODUCTION

This document describes the performance and costs associated with a modified internal combustion engine (ICE) used for the destruction of hydrocarbon vapors extracted from fuel contaminated soils. During the period of 18 October 1993 to 14 January 1994, an ICE treatment system manufactured by VR Systems Inc. in Anaheim, California was tested at the Patrick Air Force Base (AFB), Florida, active Base Exchange (BX) service station. The ICE test was conducted in conjunction with an ongoing soil vapor extraction/bioventing pilot test directed and funded by the Air Force Center for Environmental Excellence (AFCEE), Technology Transfer Division (ERT). The purpose of this test was to independently measure both the performance and the cost of ICE operation, and to determine how this technology can be most effectively used to complement the bioventing technology.

Bioventing is an *in situ* remediation technology which is best suited for less volatile hydrocarbons commonly found in jet fuels, diesel fuels, and heating oils. Bioventing can be accomplished through air injection or extraction; however, injection of air into sites contaminated with more volatile hydrocarbon products (e.g., gasoline) can result in uncontrolled migration of high concentrations of volatile organic compounds (VOCs). One solution to this problem is the use of soil vapor extraction techniques during the initial months of remediation to remove and treat high levels of soil gas VOCs. Additionally, while the VOCs are being extracted from the soil, they are displaced by atmospheric air which contains the oxygen (i.e., electron acceptor) required to subsequently promote *in situ* biodegradation. This short period of vapor extraction is then followed by long-term air injection to provide oxygen for the biodegradation of less volatile or adsorbed hydrocarbons in the soil.

In many states, VOCs must be treated before discharge into the atmosphere. In the State of Florida, soil vapor extraction must include a vapor treatment technology capable of removing 99 percent of the VOCs prior to discharge. Activated carbon cannisters and thermal destruction units, such as ICEs, are used for treatment of hydrocarbon vapors. Significant information on the performance and cost of activated carbon is already available. Less information is available on ICE performance, particularly data that have been independently measured and verified.

This document is organized into five sections including this introduction. Section 2 provides a more complete description of the technology and the vendor's information on performance and cost. Section 3 reports the results of the 3-month field test with an emphasis on VOC destruction efficiency, operating costs, and reliability and

maintainability issues. Section 4 provides a summary of this technology evaluation and discusses how this technology can best be integrated into an *in situ* bioventing project. Section 5 includes the references cited in this report.

SECTION 3

FIELD DEMONSTRATION RESULTS

3.1 SITE DESCRIPTION

An extended pilot study evaluation of the Model V3 vapor extraction ICE unit was conducted between October 18, 1993 and January 14, 1994. The field demonstration was performed at Patrick AFB, Florida at the BX Service Station.

The BX Service Station site is part of an ongoing bioventing pilot test study. Soil and groundwater contamination exists from previous unleaded gasoline leaks from underground storage tanks (USTs). A soil gas survey was initially conducted to verify site conditions, and to ensure that sufficient soil contamination existed to conduct the bioventing pilot test. The initial soil gas sample laboratory results ranged from 38,000 parts per million, volume per volume (ppmv) to 100,000 ppmv for total volatile hydrocarbons (TVH) within the study area (ES, 1993).

The average water table depth is approximately 5 feet below ground surface (bgs). A horizontal vent well (HVW) was installed at 4 feet bgs as part of the bioventing pilot test. The HVW was placed in the center of the highest TVH readings obtained during the initial soil gas survey at this site. The HVW was constructed of 4-inch, Schedule 40 polyvinyl chloride (PVC) pipe with 30 feet of 0.03-inch slotted well screen. The entire length of screened interval was placed within the contaminated soil area. The entire study area at this site is paved, which significantly reduces or eliminates the potential for short-circuiting and increases the area of influence for air injection or soil vapor extraction through the HVW.

Because initial soil vapor concentrations at this site were very high, bioventing through the use of air injection was ruled out due to the potential for vapor migration. Soil vapor extraction was required to significantly reduce soil vapor concentrations before the system could be converted to a more standard air injection bioventing system. Several emission control technologies were evaluated based on efficiency, maximum TVH influent concentration capacities, maintenance requirements, and cost over the period necessary for vapor extraction. Based on the technology review, a decision was made to use the ICE vapor extraction system manufactured by VR Systems, Inc. and to evaluate its performance and cost of operation.

3.2. REGULATORY APPROVAL/REQUIREMENTS

Florida Department of Environmental Protection (FDEP) policy states that all vacuum extraction units must use a catalytic or thermal oxidation device, or its

equivalent (carbon absorption), to reduce VOC emissions by at least 99 percent during the first two months of operation. After 2 months of operation, the reduced untreated effluent concentrations are evaluated with the SCREEN air modeling program. If the results show that the emissions are below acceptable ambient air standards at the area of greatest impact, the air emissions controls may be discontinued after concurrence from the FDEP.

3.3 TEST CONDITIONS

Table 2.2 provides the performance specifications for the V3 model. The range of extraction flow rates for this model is 0 to 250 scfm, with a vacuum capacity of up to 245 inches of water. During the initial 2-day demonstration, a maximum flow rate of 150 scfm was established. This flow rate was used because it was the maximum achievable through the HVW and required the least amount of supplemental fuel. During the extended test, an average flow rate of 80 scfm was used. The reduction in flow from 150 scfm to 80 scfm was due primarily to a higher water table condition which restricted air flow through the HVW. When a higher vapor extraction flow rate was attempted, the greater vacuum produced a mounding of the water table into the HVW.

A 55-gallon condensate knockout drum was installed between the HVW and the VR Systems unit. The drum was installed to reduce the potential for high-humidity soil gas (>95% relative humidity) condensing and accumulating within the intake hose and filter assembly that would result in a high- water shut down of the system. Following the installation of the drum, no significant accumulation of condensate occurred in the lines.

Propane was used as the supplemental fuel during the test. For the extended test period, a 500-gallon propane tank was setup approximately 30 feet from the VR System unit. During the test period, a local propane distributor would top off the propane tank approximately twice per week. This servicing was performed with the system operating and no supervision was needed during this activity.

3.4 OBSERVED PERFORMANCE

3.4.1 Initial 2-Days at 150 SCFM

Table 3.1 reflects the changes in influent concentrations over time for TVH and BTEX during the initial 2 days of the test. The average flow rate during this period was 150 scfm at an average engine speed of 1,790 rpm. Due to the age and natural weathering of the gasoline spill, initial BTEX concentrations at this site comprised a relatively small fraction of the TVH.

TABLE 3.1

CHANGE IN INFLUENT CONCENTRATIONS FOR TVH
AND BTEX OVER TIME @ 150 SCFM
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION
PATRICK AFB, FLORIDA

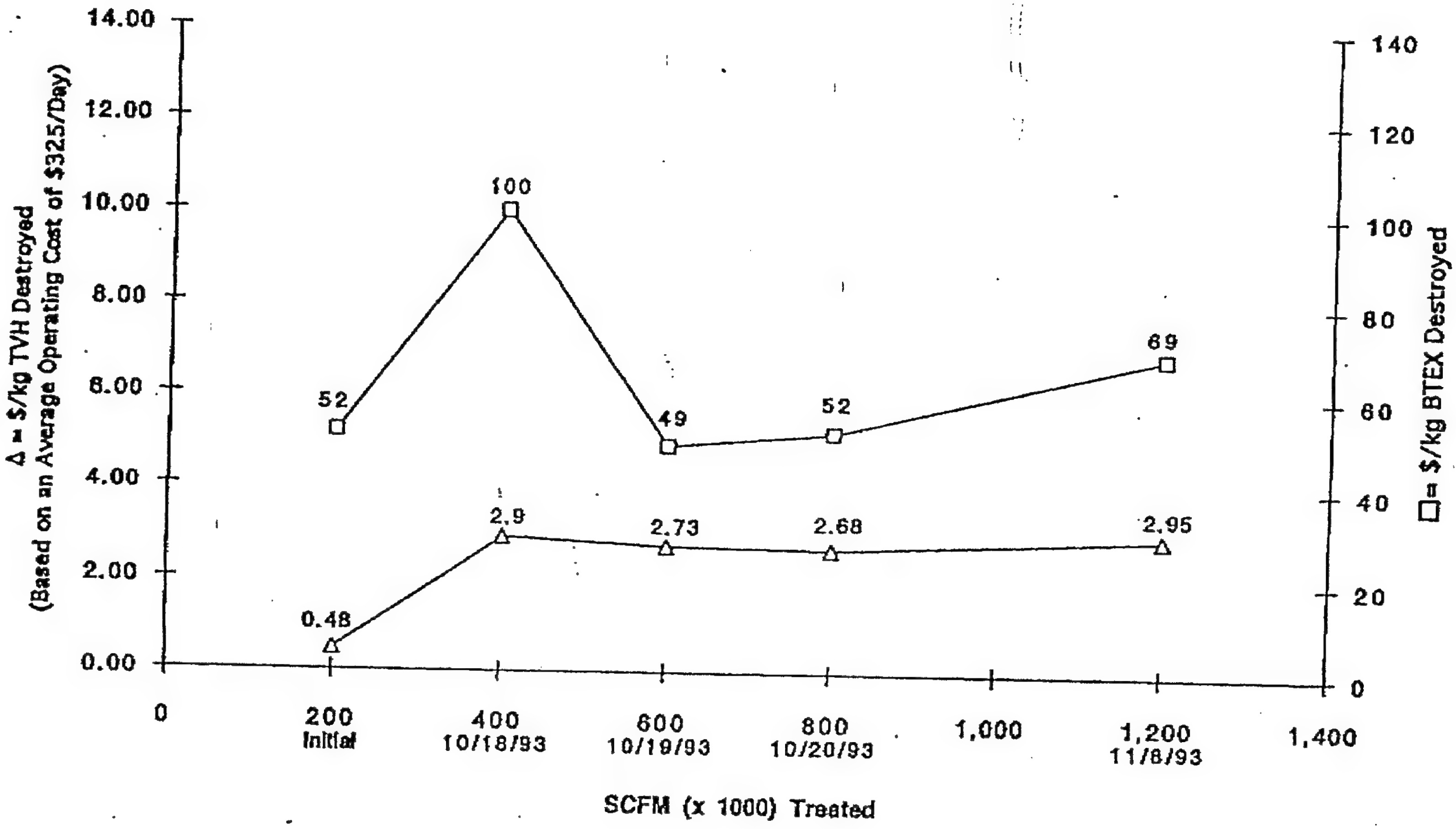
Influent Constituent	Concentrations Initial (ppmv)	After 2-Days (ppmv)
TVH	47,000	7,800
Benzene	--[a]	--[a]
Toluene	15	4.7
Ethylbenzene	14	12
Xylenes	200	110

[a] Below Detection Limit.

During the 2-day initial test period, a variety of rpm ranges were used to find the optimum engine speed which yielded the highest vapor flow from the well, while using the least amount of supplemental propane. Also, during the initial 13 hours of operation, the VR System engine was treating a severely oxygen-depleted soil gas. Bioactivity in the area had completely depleted soil gas oxygen supplies. Adjustments by the onboard computer of the influent flow rates were made to maintain the proper oxygen/fuel ratio and a VOC destruction efficiency of >99 percent. As the influent soil gas was oxygen depleted (<2%), the computer had to compensate by adding dilution air through the carburetor and supplemental propane until the soil gas oxygen supply increased to greater than 17 to 18 percent. The majority of the supplemental fuel used over the course of the 2-day test was consumed during this initial 13-hour adjustment period.

Propane consumption during the initial 2 days (44 hours) was 1,925 cubic feet (cf) at an average rate of 43.75 cf/hour. Propane costs during this test were $0.80 per gallon. Using a conversion factor of 36 cf/gallon of propane, an average cost for the supplemental fuel propane was approximately $1.00/hr. Based on laboratory influent and effluent sampling results, the cost per kilogram (kg) of TVH and BTEX destroyed was calculated. Based on the laboratory results and an initial flow rate of 150 scfm, a graphical representation of the cost per kg of TVH and BTEX destroyed was generated for the initial 800,000 scfm of soil gas treated during the first 5 days of operation (Figure 3.1). During this period, the average operating cost was $325.00 per day. A breakdown of the daily operating cost is as follows:

Figure 3.1
Cost Per Kilogram of BTEX and TVH Destroyed
at 150 SCFM Initial Flow Rate



- Equipment rental $230.00/day,
- Supplemental fuel (propane) $24.00 to $57.00/day, and
- Labor (1 hour per day) $50.00/hour to check on and sample system.

As the actual daily costs ranged from $305.00 to $337.00, an average daily cost of $325.00 was used.

During the initial startup of vapor extraction, the soil gas being removed will typically be oxygen depleted and contain elevated concentrations of inert gases, such as methane, which are produced by the *in situ* biological activity. During the initial 800,000 scfm of soil gas removal at Patrick AFB, a wide range of operating costs were observed. After the initial soil gas has been displaced by oxygenated soil gas, the need for dilution air subsided and contaminant destruction rates became more uniform.

The ratio of BTEX to TVH at this site is not representative of a recent spill or leak, where BTEX comprises up to 20 percent of the TVH. It appears that the majority of the BTEX constituents normally expected within unweathered gasoline were no longer present. During the initial startup period at this site, the BTEX percentage of TVH averaged 5 percent, indicating an older, weathered fraction of gasoline. The cost for each kg of BTEX destroyed will vary based on the site-specific BTEX concentrations.

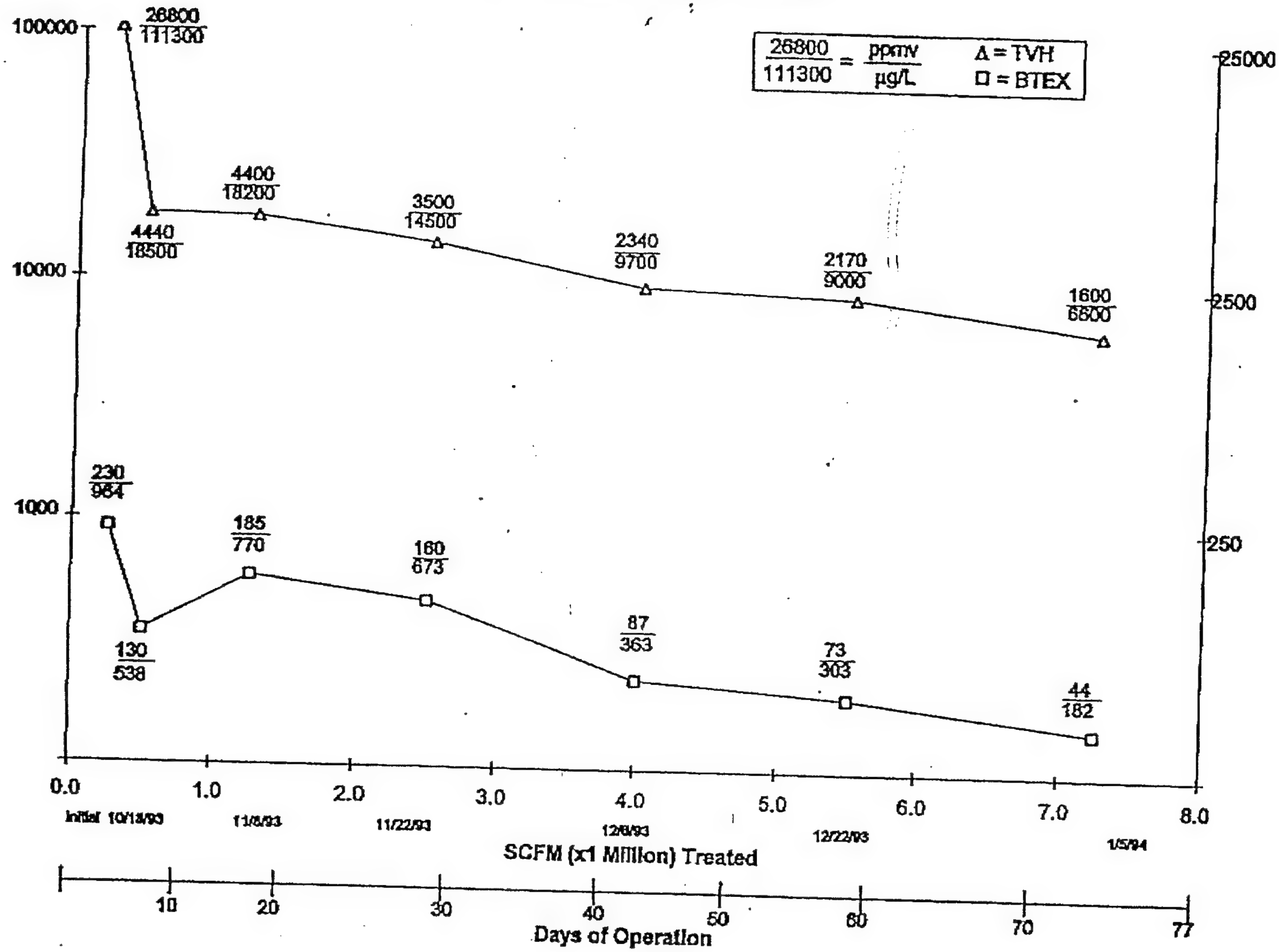
3.4.2 Long-Term (Weeks 2-13) Performance

During the extended test period, the average flow rate was reduced from 150 scfm (initially) to 80 scfm due to a higher water table which reduced the HVW efficiency. Along with a reduction in influent flow rates, the onboard computer was programmed to operate the engine to create between 7 and 11 inches of water vacuum to prevent high-water shut down of the equipment. Limitations placed on the vacuum reduced the efficiency of the V3 unit. Despite these inefficiencies, the primary goals of determining the destruction efficiency, operating cost range, reliability, and maintainability were successfully achieved during the evaluation.

3.4.3 Destruction Efficiency

The VR System provided greater than 99-percent destruction efficiency for BTEX and greater than 96-percent destruction efficiency for TVH throughout the test period. Figure 3.2 illustrates the range of soil gas influent BTEX and TVH concentrations encountered during the test and the significant reduction that occurred as a result of 80 days of soil vapor extraction and ICE treatment. Figure 3.3 illustrates the destruction efficiencies that were achieved. A 4-percent reduction in TVH destruction efficiency occurred when the engine rings and valves began to wear, allowing a fraction of the supplemental propane to pass unburned through the engine exhaust. When a new replacement unit was installed at the site, destruction efficiencies returned to greater than 99 percent for all hydrocarbons. It is important to note that laboratory analysis confirmed that the unburned fuel was propane and not BTEX compounds from the soil vapor extraction system. Weekly monitoring of influent and effluent TVH is

Figure 3.2
Influent BTEX and TVH Concentration Reduction over Total SCFM Treated



APPENDIX B

LABORATORY ANALYTICAL REPORTS

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30A0101
Phone: (614) 424-6199
Attn: Al Pollack

Sampled: 08/27/95 Received: 08/29/95 Analyzed: 08/30-09/12/95

Matrix: [ ] Soil [X] Water [ ] Waste

Analysis Requested: TPH (Gasoline) - Total Petroleum Hydrocarbons-Purgeable Quantitated as Gasoline
TPH (Diesel) - Total Petroleum Hydrocarbons-Extractable Quantitated as Diesel
BTXE - Benzene, Toluene, Xylenes, Ethylbenzene

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTXE - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
Effluent #1 /BMI082995-01	TPH (Gasoline)	ND	0.50	mg/L
	TPH (Diesel)	ND	1.0	mg/L*
	Benzene	ND	1.0	ug/L
	Toluene	2.8	1.0	ug/L
	Total Xylenes	2.8	1.0	ug/L
	Ethylbenzene	ND	1.0	ug/L
Effluent #2 /BMI082995-02	TPH (Gasoline)	ND	0.50	mg/L
	TPH (Diesel)	ND	1.0	mg/L*
	Benzene	ND	1.0	ug/L
	Toluene	2.8	1.0	ug/L
	Total Xylenes	2.6	1.0	ug/L
	Ethylbenzene	ND	1.0	ug/L
OWS #1 /BMI082995-03	TPH (Gasoline)	33	25	mg/L
	TPH (Diesel)	960	1.0	mg/L*
	Benzene	2,100	50	ug/L
	Toluene	2,200	50	ug/L
	Total Xylenes	5,200	50	ug/L
	Ethylbenzene	1,000	50	ug/L

Alpha Analytical, Inc.
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(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

Continued:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
Pretreatment #1	TPH (Gasoline)	51	25	mg/L
/BMI082995-04	TPH (Diesel)	220	1.0	mg/L*
	Benzene	1,700	50	ug/L
	Toluene	1,800	50	ug/L
	Total Xylenes	4,000	50	ug/L
	Ethylbenzene	810	50	ug/L
Pretreatment #2	TPH (Gasoline)	100	25	mg/L
/BMI082995-05	TPH (Diesel)	130	1.0	mg/L*
	Benzene	1,700	50	ug/L
	Toluene	1,900	50	ug/L
	Total Xylenes	4,600	50	ug/L
	Ethylbenzene	930	50	ug/L

* - Detection limit was increased due to the small sample volume provided by the client.

ND - Not Detected

Approved by: Roger L. Scholl Date: 9/18/95
Roger L. Scholl, Ph.D.
Laboratory Director

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. 002

Proj. No. G462201-30A0101

Project Title Bioslurper DOVER AFB

SAMPLERS: (Signature) Greg Headington / JON Eastep

DATE	TIME	SAMPLE I.D.	SAMPLE TYPE (√): BTEX/TPH Extractable and Purgeable	Container No.	Number of Containers	Remarks
27AUG95	0945	Effluent #1	X		3	Clay/Carbon treated
27AUG95	~~0945~~	Effluent #2	X		3	Clay/Carbon treated
27AUG95	1010	OWS-#1	X		3	Down stream of separator
27AUG95	1025	Pretreatment #1	X		3	settling tank
27Aug95	1025	Pretreatment #2	X		3	Settling tank

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Greg Headington	27Aug95 1035				

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks
		[illegible signature]	8/27/95 1930	SEND RESULTS TO: Al Pollack Battelle 505 KING AVE. Columbus, OH 43201

Page 1 of 1

Billing Information:

Name
Address
City, State, Zip
Phone Number

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Project Page # 1 of 1

Client Name: Battelle
P.O. #: 874662201-30A0101
Address
Phone #
City, State, Zip
Report Attention: Al Pollack

Sampled by: Client

Time Sampled	Date Sampled	Type* See Key Below	Lab ID Number	Sample Description	Number of Containers	TPH	TPH gas	BTXE						Remarks
	8/27	AQ	BMI082795-01	Effluent #1	3	X	X	X						
	✓	✓	02	Effluent #2	3	X	X	X						
	✓	✓	03	CWS #1	3	X	X	X						
	✓	✓	04	Pretreatment #1	3	X	X	X						
	✓	✓	05	Pretreatment #2	3	X	X	X						

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	[signature]	Linda Lerner	AAI	8/29/95	0930
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - OTher

Laboratory Analysis Report

Sierra Environmental Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 9/06/95
Client : ALP-855
Taken by: CLIENT
Report : 14112
PO# :

Page: 1

Sample	Collected Date	Time	MOISTURE CONTENT %	DENSITY G/CM3	POROSITY %			
BMI082395-01/03 COMP - DOVER	8/21/95	:	10.4%	1.01	61.9%			
BMI082395-04/06 COMP - DOVER	8/21/95	:	11.0%	1.02	61.5%			

Rec. 9-18-95

Approved By: [signature]

This report is applicable only to the sample received by the laboratory. The liability of the laboratory is limited to the amount paid for this report. This report is for the exclusive use of the client to whom it is addressed and upon the condition that the client assumes all liability for the further distribution of the report or its contents.

William F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: 6462201-30A0101
Phone: (614) 424-5412
Attn: Al Pollock

Sampled: 08/21/95 Received: 08/23/95 Analyzed: 08/25/95

Matrix: [X] Soil [ ] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline
BTXE - Benzene,Toluene,Xylenes,Ethylbenzene

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTXE - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
Dover #3 - 8.5-9.0 /BMI082395-03	TPH (Purgeable)	580	20	mg/Kg
	Benzene	1,200	40	ug/Kg
	Toluene	5,800	40	ug/Kg
	Total Xylenes	23,000	40	ug/Kg
	Ethylbenzene	5,600	40	ug/Kg
Dover #6 - 10.0-10.5 /BMI082395-06	TPH (Purgeable)	1,300	20	mg/Kg
	Benzene	20,000	40	ug/Kg
	Toluene	2,400	40	ug/Kg
	Total Xylenes	45,000	40	ug/Kg
	Ethylbenzene	1,200	40	ug/Kg

Approved by: Roger L. Scholl Date: 8/29/95
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Billing Information:
Name
Address
City, State, Zip
Phone Number

Page # 1 of 1

Client Name: Battelle
Address:
City, State, Zip:
P.O. #: 4G2201-30A0101
Phone #: (614) 424-5412
Report Attention: Al Pollack
Sampled by:

Time Sampled	Date Sampled	Type* See Key Below	Lab ID Number	Sample Description	Number of Containers	TPH/GAS	BTXE	Bulk Density	Porosity	Moisture Content					Remarks
	8/21	SO	BMI082375-01	Dover #1 - 7.5 - 8.0	1			X	X	X					
	✓	✓	02	Dover #2 - 8.0 - 8.5	1			X	X	X					Do the gas/BTX
	✓	✓	03	Dover #3 - 8.5 - 9.0	1	X	X	X	X	X					individually.
	✓	✓	04	Dover #4 - 9.0 - 9.5	1			X	X	X					Then composite
	✓	✓	05	Dover #5 - 9.5 - 10.0	1			X	X	X					.01-03 + 04-06
	✓	✓	06	Dover #6 - 10.0 - 10.5	1	X	X	X	X	X					for the [illegible]

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	[illegible]	Linda LERNER	AAI	8/23/95	1015
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

[redacted]ey: A[redacted]ueou[redacted] SO[redacted] [redacted]-Wa[redacted] O[redacted]ther [redacted]

Battelle
Columbus Laboratories

DATA to:
AL POLLACK (Battelle

CHAIN OF CUSTODY RECORD

TO ALPHA ANALYTICAL

Form No. 001

Proj. No.	Project Title
6462201-30A0101	Bioslurper DOVER AFB

SAMPLERS: (Signature) [signature] (614) 424-5417

DATE	TIME	SAMPLE I.D.	BTEX/TPH As Gasoline	Bulk Density	Porosity	Moisture Content	Container No.	Number of Containers	Remarks
21AUG95		DOVER #1 - 7.5 - 8.0		X	X	X	1		combine
		DOVER #2 - 8.0 - 8.5		X	X	X	1		
		DOVER #3 - 8.5 - 9.0	X	X	X	X	1		BTEX/TPH
		DOVER #4 - 9.0 - 9.5		X	X	X	1		combine
		DOVER #5 - 9.5 - 10.0		X	X	X	1		
		DOVER #6 - 10.0 - 10.5	X	X	X	X	1		BTEX/TPH

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
[signature]	22AUG95 1000				

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks
		[signature]	8/23/95 1015	ANALYZE FOR BTEX/TPH then combine 1-2-3 AS ONE SAMPLE. 4-[redacted] BTEX/TPH the

Page [redacted] of [redacted]

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30A0101
Phone: (614) 424-6122
Attn: Al Pollack

Alpha Analytical Number: BMI082995-06

Client I.D. Number: Fuel #1 (JP-4)

Compound	Method	Concentration ug/Kg	Detection Limit ug/Kg	Date Analyzed
Benzene	8240	1,300,000.00	500,000.00	08/30/95
Toluene	8240	3,800,000.00	500,000.00	08/30/95
Total Xylenes	8240	19,000,000.00	500,000.00	08/30/95
Ethylbenene	8240	4,000,000.00	500,000.00	08/30/95
C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
C9<	GC/FID	45.5	NA	09/06/95
C10	GC/FID	11.3	NA	09/06/95
C11	GC/FID	12.4	NA	09/06/95
C12	GC/FID	13.2	NA	09/06/95
C13	GC/FID	10.9	NA	09/06/95
C14	GC/FID	4.9	NA	09/06/95
C15>	GC/FID	1.9	NA	09/06/95

Approved by: Roger L. Scholl

Roger L. Scholl, Ph.D.
Laboratory Director

Date: 9/12/95

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. 003

Proj. No.	Project Title
G 462201-30A0101	Bioslurper Dover AFB

SAMPLERS: (Signature) Greg Headington / JON EASTEP

DATE	TIME	SAMPLE I.D.	SAMPLE TYPE (√): BTEX/TPH Extractable (Boiling Point Range)	Container No.	Number of Containers	Remarks
25 AUG 95	—	Fuel # 1 (JP4)	X	'	1	

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Greg Headington	27 AUG 1000				

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks
		[illegible signature]	8/28/95 0730	Results to: AL POLLACK BATTELLE, 505 KING AVE, Columbus, OH, 43201 FAX (614) 424-366[illegible]

Page 1 of 1

Billing Information:
Name
Address
City, State, Zip
Phone Number

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Page # 1 of 1

Client Name Battelle	P.O. # G462201-3070101
Address	Phone #
City, State, Zip	Report Attention Al Pollack

Sampled by Client

Time Sampled	Date Sampled	Type* See Key Below	Lab ID Number	Sample Description	Number of Containers	TPH	BTXE	Distillation						Remarks
	8/25	OT	BMI082975-06	Fuel #1 (JP4)	1	X	X	X						

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	Linda Lerner	Linda LERNER	AAI	8/29/95	0930
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

[redacted]y: A[redacted]ueou[redacted] SO[redacted] [redacted]- Wa[redacted] O[redacted]her [redacted]

@ AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 9508255

Work Order Summary

CLIENT: Mr. Eric Dreschler
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

BILL TO: Same

PHONE: 614-424-3753
FAX: 614-424-3667
DATE RECEIVED: 8/30/95
DATE COMPLETED: 9/6/95

INVOICE # 7897
P.O. # 91221
PROJECT # G462201-30A0101 Bioslurper/Dover AFB
AMOUNT$: $701.38

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	PRICE
01A	9529/1143 ICE #1	TO-3	2.0 "Hg	$120.00
02A	9398/0836 ICE #2	TO-3	2.0 "Hg	$120.00
03A	9443/0747 SEAL GAS #1	TO-3	1.5 "Hg	$120.00
04A	9505/0952 SEAL GAS #2	TO-3	1.0 "Hg	$120.00
05A	9432/0936 ICE #3-BLK	TO-3	0.2 psi	$120.00
06A	Lab Blank	TO-3	NA	NC

Misc. Charges	1 Liter Summa Canister Preparation (5) @ $10.00 each.	$50.00
	Shipping (8/18/95)	$51.38

CERTIFIED BY: Linda L. Freeman
Laboratory Director

DATE: 9/6/95

AIR TOXICS LTD.

SAMPLE NAME: 9529/1143 ICE #1

ID#: 9508255-01A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6083119		Date of Collection: 8/27/95	
Dil. Factor:	110		Date of Analysis: 8/31/95	

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.11	0.36	1.9	6.2
Toluene	0.11	0.42	2.1	8.0
Ethyl Benzene	0.11	0.49	0.45	2.0
Total Xylenes	0.11	0.49	1.3	5.7

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6083119		Date of Collection: 8/27/95	
Dil. Factor:	110		Date of Analysis: 8/31/95	

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	1.1	7.1	220	1400
C2 - C4** Hydrocarbons	1.1	2.0	18	33

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: 9398/0836 ICE #2

ID#: 9508255-02A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6083121		Date of Collection: 8/27/95	
Dil. Factor:	2.2		Date of Analysis: 8/31/95	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	0.002	0.007	0.005	0.016
Toluene	0.002	0.008	0.007	0.027
Ethyl Benzene	0.002	0.010	0.004	0.018
Total Xylenes	0.002	0.010	0.011	0.048

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6083121		Date of Collection: 8/27/95	
Dil. Factor:	2.2		Date of Analysis: 8/31/95	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	0.022	0.14	4.0	26
C2 - C4** Hydrocarbons	0.022	0.04	0.17	0.31

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: 9443/0747 SEAL GAS #1
ID#: 9508255-03A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	**6083122**		**Date of Collection: 8/27/95**	
Dil. Factor:	**18000**		**Date of Analysis: 8/31/95**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	18	58	250	810
Toluene	18	69	310	1200
Ethyl Benzene	18	79	85	380
Total Xylenes	18	79	270	1200

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name:	**6083122**		**Date of Collection: 8/27/95**	
Dil. Factor:	**18000**		**Date of Analysis: 8/31/95**	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	180	1200	23000	150000
C2 - C4** Hydrocarbons	180	330	1600	2900

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: 9505/0952 SEAL GAS #2
ID#: 9508255-04A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	**6083120**		**Date of Collection: 8/27/95**	
Dil. Factor:	**26000**		**Date of Analysis: 8/31/95**	

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	26	84	260	840
Toluene	26	100	300	1100
Ethyl Benzene	26	110	70	310
Total Xylenes	26	110	210	930

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name:	**6083120**		**Date of Collection: 8/27/95**	
Dil. Factor:	**26000**		**Date of Analysis: 8/31/95**	

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	260	1700	19000	120000
C2 - C4** Hydrocarbons	260	480	1600	2900

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: 9432/0936 ICE #3-BLK

ID#: 9508255-05A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6083124		Date of Collection: 8/29/95	
Dil. Factor:	2.0		Date of Analysis: 8/31/95	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	0.002	0.006	Not Detected	Not Detected
Toluene	0.002	0.008	Not Detected	Not Detected
Ethyl Benzene	0.002	0.009	Not Detected	Not Detected
Total Xylenes	0.002	0.009	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6083124		Date of Collection: 8/29/95	
Dil. Factor:	2.0		Date of Analysis: 8/31/95	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	0.020	0.13	0.15	0.97
C2 - C4** Hydrocarbons	0.020	0.037	0.64	1.2

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank

ID#: 9508255-06A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6083105		Date of Collection: NA	
Dil. Factor:	1.0		Date of Analysis: 8/31/95	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	0.001	0.003	Not Detected	Not Detected
Toluene	0.001	0.004	Not Detected	Not Detected
Ethyl Benzene	0.001	0.004	Not Detected	Not Detected
Total Xylenes	0.001	0.004	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6083105		Date of Collection: NA	
Dil. Factor:	1.0		Date of Analysis: 8/31/95	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	0.010	0.065	Not Detected	Not Detected
C2 - C4** Hydrocarbons	0.010	0.018	Not Detected	Not Detected

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA

AIR TOXICS LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY

180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

CHAIN-OF-CUSTODY RECORD

No 004638
Page ___ of ___

Contact Person AL POLLACK / BIOSLURPER PROJECT
Company BATTELLE
Address 505 KING AVE City Columbus State OH Zip 43201
Phone ________ FAX (614) 424-3667
Collected By: Signature JON EASTEP

Project info: #91221
P.O. # [illegible]
Project # G462201-30A0101
Project Name Bioslurper/ DOVER AFB

Turn Around Time:
☒ Normal
☐ Rush ________ Specify

Lab I.D.	Field Sample I.D.	Date & Time	Analyses Requested	Canister Pressure / Vacuum Initial	Final	Receipt
01A	9529/1143 ICE #1	27 AUG / 1106		+	0"	2.0"Hg
02A	9398/0836 ICE #2	27 AUG / 1111			0"	2.0"Hg
03A/B	9443/0747 SEAL GAS #1	27 AUG / 1117			0"	1.5"Hg
04A	9505/0952 SEAL GAS #2	27 AUG / 1126			0"	1.0"Hg
05A	9432/0936 ICE #3-BLK	29 AUG / 0712		29"	0"	0.2"Hg
	BARCODE #0659	—	CAN HAD NO VACUUM	0"		

KR

Relinquished By: (Signature) [signature] Date/Time 29AUG95/1035 Print Name Greg Headington (614) 424-5417
Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time
Relinquished By: (Signature) Date/Time Received By: (Signature) Anne E. Wilhoit AT Date/Time 8/30/95 9:55

Notes: ICE SAMPLES collected at 87.9°F
SEAL GAS collected ~~at~~ 29.9°C

Lab Use Only	Shipper Name	Air Bill #	Opened By:	Date/Time	Temp. (°C)	Condition	Custody Seals Intact?	Work Order #
	FedX	435 7986 931	aw	8/30/95 9:55	Ambient	Good	Yes No (None) N/A	9508255

Form [redacted] v. 06

APPENDIX C

OPERATIONAL DATA FOR THE ICE

08/24/95 12:00:00 UNIT 182

100	1518.	162.F	166.F	701.F	53.	15.4	-2.4	0.	-0.	13.2	57.8	0.584	1.73	5	503	23.

Start Skimming Test at 1200 HR

V.R.SYSTEMS INC.   16 min into skimming

MODEL V3 S/N 182
PERMIT NO.

Flow   PROPANE

	ENGINE RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	-VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	-UNITS	ENGINE HOURS
08/24/95 12:16:20 UNIT 182																
100	1752.	164.F	168.F	759.F	53.	17.3	-2.4	0.	-0.	13.3	59.9	0.580	1.90	5	534	23.
08/24/95 12:20:58 UNIT 182																
100	2543.	167.F	175.F	959.F	53.	24.1	-2.4	42.	-1.	13.4	54.4	0.591	0.00	5	538	23.
08/24/95 12:24:32 UNIT 182																
100	2538.	173.F	188.F	1011.F	53.	24.1	-2.4	42.	-1.	13.2	52.6	0.595	1.14	5	542	23.
08/24/95 12:28:04 UNIT 182																
100	2415.	176.F	192.F	1001.F	52.	22.0	-2.4	43.	-1.	12.9	57.2	0.586	0.93	5	546	23.
08/24/95 12:30:00 UNIT 182																
100	2407.	177.F	194.F	1000.F	52.	22.0	-2.4	43.	-1.	13.0	58.9	0.582	1.01	5	548	23.
08/24/95 12:32:31 UNIT 182																
100	2434.	178.F	196.F	1000.F	52.	22.0	-2.4	44.	-1.	12.9	59.0	0.582	1.10	5	551	23.
08/24/95 12:39:47 UNIT 182																
100	2380.	180.F	198.F	1010.F	52.	22.0	-2.4	44.	-0.	13.0	63.1	0.574	0.00	5	556	23.
08/24/95 12:42:41 UNIT 182																
100	2570.	175.F	196.F	1035.F	52.	24.4	1.8	53.	-1.	13.1	62.0	0.576	1.16	5	559	23.
08/24/95 12:48:48 UNIT 182																
100	1712.	174.F	189.F	917.F	52.	2.0	1.5	66.	-2.	13.1	57.9	0.584	2.09	5	573	24.
08/24/95 12:49:01 LIMIT 110 BATTERY 0.0 LOW BATT. VOLT ALARM UNIT 182																
08/24/95 12:49:01 LIMIT 414 ENG TMR 6873. ENGINE FAILED ALARM UNIT 182																
08/24/95 12:49:01 UNIT 182																
100	0.	174.F	188.F	908.F	61.	-25.0	-25.0	0.	-380.	0.0	0.2	0.700	2.01	5	573	24.
¿ESTART AT: 08/24/95 13:15:19 (08/24/95 12:56:04) S5245 V2.23																
08/24/95 13:15:22 UNIT 182																
100	0.	150.F	114.F	196.F	2.	-25.0	-25.0	0.	-390.	0.0	0.1	0.700	0.00	5	573	24.
08/24/95 13:16:41 UNIT 182																
100	2038.	160.F	163.F	484.F	53.	20.3	-1.0	0.	-1.	13.7	45.1	0.610	0.00	5	574	24.
08/24/95 13:19:56 UNIT 182																
100	2519.	167.F	171.F	900.F	53.	25.2	-1.1	37.	-2.	13.4	77.7	0.545	0.00	5	576	24.
08/24/95 13:23:47 UNIT 182																
100	2561.	174.F	187.F	1013.F	52.	25.4	-1.3	43.	0.	13.3	59.4	0.581	0.00	5	576	24.
08/24/95 13:29:25 UNIT 182																
100	2566.	178.F	197.F	1036.F	52.	25.4	-1.5	42.	-1.	13.1	55.9	0.588	0.00	5	579	24.
08/24/95 13:30:00 UNIT 182																
100	2571.	178.F	198.F	1037.F	52.	25.4	-1.5	42.	-1.	13.1	59.1	0.582	0.92	5	580	24.
08/24/95 13:31:48 UNIT 182																
100	2566.	177.F	197.F	1040.F	52.	25.4	-1.6	42.	-2.	13.1	58.0	0.584	1.09	5	582	24.
08/24/95 13:35:45 UNIT 182																
100	2586.	182.F	201.F	1029.F	52.	25.4	-1.8	41.	-1.	13.1	60.1	0.580	1.65	5	587	24.
08/24/95 13:38:43 UNIT 182																
100	2356.	182.F	200.F	1013.F	52.	20.8	-0.1	51.	-1.	12.9	64.1	0.572	0.78	5	590	24.
08/24/95 13:40:03 UNIT 182																
100	2416.	182.F	200.F	1023.F	52.	21.5	-0.1	49.	-2.	12.9	61.0	0.578	0.00	5	591	24.
08/24/95 13:45:41 UNIT 182																
100	2548.	184.F	204.F	1034.F	52.	24.2	-0.2	45.	-0.	12.9	62.1	0.576	2.20	5	599	24.
08/24/95 13:47:44 UNIT 182																
100	2571.	185.F	204.F	1068.F	52.	21.1	12.3	93.	-3.	12.9	64.3	0.571	0.96	5	602	24.
08/24/95 13:49:39 UNIT 182																
100	2612.	186.F	205.F	1080.F	52.	11.6	22.9	139.	-4.	13.0	61.6	0.577	1.20	5	604	24.
08/24/95 13:59:07 UNIT 182																
100	2555.	186.F	206.F	1075.F	52.	7.8	22.7	145.	-5.	12.9	64.0	0.572	1.63	5	620	24.
08/24/95 14:00:00 UNIT 182																
100	2472.	186.F	206.F	1073.F	52.	1.9	22.7	152.	-5.	12.9	65.3	0.569	1.59	5	621	24.
08/24/95 14:03:41 UNIT 182																
100	2228.	187.F	203.F	1024.F	52.	-0.2	18.3	136.	-3.	12.9	67.4	0.565	0.97	5	625	24.

V.R.SYSTEMS INC.

MODEL V3 S/N 182
PERMIT NO.

	ENGINE RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	-VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	-UNITS	ENGINE HOURS
08/24/95 14:12:17 UNIT 182																
100	2266.	185.F	200.F	1017.F	52.	0.5	17.6	132.	-4.	13.0	66.2	0.568	1.01	5	634	25.
08/24/95 14:17:03 UNIT 182																
100	2164.	186.F	198.F	996.F	52.	-0.2	16.2	127.	-4.	12.9	67.3	0.565	0.85	5	639	25.
08/24/95 14:30:00 UNIT 182																
100	2141.	186.F	198.F	986.F	52.	-0.2	15.7	125.	-5.	12.9	67.3	0.565	0.75	5	650	25.
08/24/95 14:40:34 UNIT 182																
100	2127.	186.F	198.F	986.F	52.	-0.2	15.6	124.	-5.	12.9	66.7	0.567	0.77	5	658	25.
08/24/95 14:56:17 UNIT 182																
100	2181.	186.F	198.F	952.F	52.	-0.2	15.1	123.	-4.	12.9	67.9	0.564	0.00	5	675	25.
08/24/95 14:57:10 UNIT 182																
100	2314.	185.F	198.F	961.F	52.	-0.2	14.2	120.	-4.	12.9	49.9	0.600	0.90	5	676	25.
08/24/95 14:58:00 LIMIT 302 OIL PSI 27. LOW OIL PSI SD UNIT 182																
08/24/95 14:58:02 LIMIT 414 ENG TMR 6154. ENGINE FAILED ALARM UNIT 182																
08/24/95 15:00:00 UNIT 182																
¿ESTART AT: 08/24/95 15:02:18 (08/24/95 15:00:02) S5245 V2.23 .																
08/24/95 15:02:21 UNIT 182																
100	3.	210.F	187.F	515.F	0.	19.3	-0.4	0.	-1.	12.9	99.9	0.500	0.00	5	678	25.
08/24/95 15:05:38 UNIT 182																
100	2366.	173.F	188.F	879.F	47.	20.4	-2.0	47.	-1.	13.4	64.3	0.571	0.00	5	683	25.
08/24/95 15:07:54 UNIT 182																
100	2404.	174.F	189.F	953.F	47.	20.4	-0.8	50.	-1.	13.5	60.6	0.579	0.90	5	685	25.
08/24/95 15:09:45 UNIT 182																
100	2409.	174.F	188.F	987.F	47.	12.8	12.0	105.	-3.	13.5	60.4	0.579	0.83	5	686	25.
08/24/95 15:15:47 UNIT 182																
100	2360.	174.F	188.F	1018.F	47.	11.0	12.1	107.	-4.	13.5	62.3	0.575	0.73	5	690	26.
08/24/95 15:30:00 UNIT 182																
100	2465.	174.F	190.F	1047.F	47.	-0.3	21.7	152.	-6.	13.5	61.7	0.577	1.13	5	706	26.
08/24/95 15:32:30 UNIT 182																
100	2439.	175.F	190.F	1047.F	47.	-0.3	21.7	151.	-6.	13.5	60.1	0.580	1.14	5	709	26.
08/24/95 15:38:12 UNIT 182																
100	2217.	174.F	186.F	1007.F	47.	-0.3	17.3	132.	-5.	13.5	61.6	0.577	0.79	5	714	26.
08/24/95 16:00:00 UNIT 182																
100	2324.	173.F	187.F	1030.F	47.	-0.3	19.6	142.	-6.	13.5	61.9	0.576	cfm $\boxed{1.02}$	5	738	26. 32 cu ft.
08/24/95 16:30:00 UNIT 182																
100	2327.	175.F	188.F	1027.F	47.	-0.3	19.3	141.	-6.	13.5	62.2	0.576	1.07	5	770	27.
08/24/95 17:00:00 UNIT 182																
100	2316.	175.F	188.F	1029.F	47.	-0.3	19.3	141.	-3.	13.5	61.0	0.578	1.17	5	805	27.
08/24/95 17:30:00 UNIT 182																
100	2305.	174.F	187.F	1023.F	47.	-0.3	19.2	141.	-5.	13.5	61.5	0.577	1.20	5	842	28.
08/24/95 17:41:28 UNIT 182																
100	2313.	173.F	186.F	1025.F	47.	-0.3	19.2	140.	-5.	13.6	61.6	0.577	1.23	5	857	28.
08/24/95 18:00:00 UNIT 182																
100	2211.	174.F	185.F	1035.F	47.	-0.3	19.0	141.	-5.	13.5	64.0	0.572	0.97	5	877	28.
08/24/95 18:30:00 UNIT 182																
100	2194.	174.F	185.F	1041.F	47.	-0.3	19.3	141.	-6.	13.5	61.1	0.578	1.19	5	914	29.
08/24/95 18:31:21 UNIT 182																
100	2215.	174.F	184.F	1042.F	47.	-0.3	19.3	141.	-6.	13.5	62.5	0.575	1.22	5	915	29.
08/24/95 19:00:00 UNIT 182																
100	2212.	173.F	184.F	1045.F	47.	-0.3	19.7	142.	-6.	13.5	63.8	0.572	1.27	5	953	29.
08/24/95 19:18:13 UNIT 182																
100	2189.	172.F	183.F	1046.F	47.	-0.3	19.7	142.	-6.	13.5	60.2	0.580	1.31	5	977	30.
08/24/95 19:30:00 UNIT 182																
100	2023.	172.F	179.F	1010.F	47.	-0.3	16.3	127.	-6.	13.5	61.6	0.577	1.01	5	990	30.

V.R.SYSTEMS INC. MODEL V3 S/N 182
PERMIT NO.

ENGINE	RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	UNITS	ENGINE HOURS
08/24/95 20:00:00 UNIT 182																
100	2020.	178.F	187.F	1011.F	46.	-0.2	16.4	126.	-5.	13.3	61.7	0.577	1.05	6	23	30.
08/24/95 20:26:46 UNIT 182																
100	2060.	169.F	177.F	1000.F	47.	-0.3	17.5	131.	-6.	13.5	60.5	0.579	1.00	6	57	31.
08/24/95 20:30:00 UNIT 182																
100	2047.	171.F	179.F	1003.F	47.	-0.3	17.2	130.	-5.	13.5	60.3	0.579	1.01	6	61	31.
08/24/95 21:00:00 UNIT 182																
100	2053.	176.F	185.F	1018.F	46.	-0.3	17.3	132.	-1.	13.3	62.7	0.575	1.12	6	94	31.
08/24/95 21:30:00 UNIT 182																
100	2045.	179.F	187.F	1015.F	46.	-0.3	17.3	131.	-1.	13.3	63.7	0.573	1.14	6	130	32.
08/24/95 22:00:00 UNIT 182																
100	2026.	181.F	189.F	1016.F	46.	-0.4	17.2	131.	-1.	13.2	63.1	0.574	1.13	6	166	32.
08/24/95 22:30:00 UNIT 182																
100	2010.	183.F	192.F	1016.F	46.	-0.4	17.1	131.	-1.	13.2	66.2	0.568	1.14	6	201	33.
08/24/95 23:00:00 UNIT 182																
100	2018.	185.F	193.F	1015.F	46.	-0.4	17.0	129.	-0.	13.2	64.8	0.570	1.17	6	238	33.
08/24/95 23:30:00 UNIT 182																
100	2016.	183.F	192.F	1017.F	46.	-0.4	17.1	131.	-1.	13.2	63.8	0.572	1.19	6	275	34.
08/25/95 00:00:00 UNIT 182																
100	2030.	174.F	186.F	1015.F	46.	-0.4	17.1	131.	-2.	13.3	62.6	0.575	1.22	6	313	34.
08/25/95 00:30:00 UNIT 182																
100	2030.	168.F	178.F	1011.F	46.	-0.3	17.2	131.	-2.	13.4	59.4	0.581	1.24	6	351	35.
08/25/95 01:00:00 UNIT 182																
100	2048.	165.F	176.F	1006.F	47.	-0.3	17.2	130.	-2.	13.4	56.2	0.588	1.26	6	391	35.
08/25/95 01:30:00 UNIT 182																
100	2072.	164.F	175.F	1000.F	47.	-0.3	17.0	129.	-2.	13.5	56.3	0.587	1.29	6	431	36.
08/25/95 02:00:00 UNIT 182																
100	2046.	164.F	173.F	993.F	47.	-0.3	16.7	128.	-2.	13.6	55.3	0.589	1.27	6	471	36.
08/25/95 02:30:00 UNIT 182																
100	2042.	165.F	174.F	988.F	47.	-0.3	16.3	127.	-2.	13.5	56.6	0.587	1.26	6	511	37.
08/25/95 03:00:00 UNIT 182																
100	2039.	163.F	173.F	986.F	47.	-0.3	16.3	127.	-2.	13.6	53.6	0.593	1.29	6	551	37.
08/25/95 03:30:00 UNIT 182																
100	2053.	163.F	173.F	981.F	47.	-0.3	15.8	125.	-3.	13.5	55.9	0.588	1.26	6	591	38.
08/25/95 04:00:00 UNIT 182																
100	2046.	164.F	173.F	982.F	47.	-0.3	15.8	124.	-2.	13.5	55.7	0.589	1.26	6	630	38.

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08/25/95 05:00:00  UNIT 182
100  2049.    163.F   171.F   951.F   47.   -0.3   14.0   119.   -1.   13.6   53.4  0.593   1.21    6   708   39.
08/25/95 05:30:00  UNIT 182
100  2037.    162.F   171.F   944.F   47.   -0.3   13.7   118.   -1.   13.7   53.9  0.592   1.16    6   745   40.
08/25/95 06:00:00  UNIT 182
100  2052.    163.F   170.F   937.F   47.   -0.3   13.3   117.   -1.   13.7   51.7  0.597   1.16    6   781   40.
08/25/95 06:30:00  UNIT 182
100  2029.    162.F   170.F   935.F   47.   -0.3   13.3   117.   -1.   13.7   52.4  0.595   1.17    6   818   41.
08/25/95 07:00:00  UNIT 182
100  2020.    163.F   170.F   934.F   47.   -0.3   13.3   116.   -1.   13.7   52.1  0.596   1.18    6   855   41.
08/25/95 07:30:00  UNIT 182
100  2054.    162.F   170.F   861.F   47.   -0.3    8.8   100.    1.   13.7   50.2  0.600   2.30    6   900   42.
08/25/95 07:39:04  UNIT 182
100  2070.    161.F   170.F   850.F   47.   -0.3    8.7   100.    1.   13.8   50.9  0.598   2.32    6   921   42.
08/25/95 08:00:00  UNIT 182
100  2056.    163.F   169.F   949.F   52.   -0.2   13.7   118.   -1.   13.8   51.9  0.596   0.87    6   950   42.
08/25/95 08:30:00  UNIT 182
100  2021.    163.F   170.F   947.F   52.   -0.3   13.3   117.   -1.   13.7   52.9  0.594   1.15    6   984   43.


     V.R.SYSTEMS INC.                MODEL V3 S/N 182
                                     PERMIT NO.

     ENGINE        TEMPERATURE -       OIL     POSITIONS       WELL FLOW    BATTERY   DUTY  PERCENT   AUXILIARY FUEL      ENGINE
       RPM     COOLANT   OIL   EXHAUST  PSI   CARB.  BYPASS   CFM-VAC.H2O    VOLTS   CYCLE  OXYGEN  CFM THOUSANDS-UNITS   HOURS

08/25/95 09:00:00  UNIT 182
100  2049.    163.F   170.F   937.F   52.   -0.3   13.2   117.   -1.   13.7   50.9  0.598   1.18    7    20   43.
08/25/95 09:30:00  UNIT 182
100  2018.    161.F   171.F   951.F   52.   -0.3  -13.2   117.   -1.   13.6   55.9  0.588   1.17    7    57   44.
08/25/95 10:00:00  UNIT 182
100  2030.    167.F   175.F   959.F   52.   -0.3   13.4   118.   -0.   13.5   58.1  0.584   1.17    7    94   44.
08/25/95 10:10:57 LIMIT  414 ENG TMR  OVRNG    ENGINE FAILED ALARM    UNIT 182        Stop skim test
08/25/95 10:14:32  UNIT 182                                                             At 1008
100     0.    192.F   153.F   573.F    2.  -25.0  -25.0     0.  -382.    0.0    0.1  0.700   0.00    7   108   44.
¿ESTART AT: 08/25/95 10:32:10 (08/25/95 10:14:40) S5245  V2.23 .
08/25/95 10:32:13  UNIT 182
100     0.    156.F   101.F   227.F   77.  -25.0  -25.0     0.  -393.    0.0    0.1  0.700   0.00    7   109   44.
08/25/95 10:39:48  UNIT 182
100  1587.    161.F   158.F   747.F   52.   -0.3    1.2    66.    1.   13.9   45.9  0.608   1.68    7   116   45.
08/25/95 10:39:49 LIMIT  110 BATTERY    0.0   LOW BATT. VOLT ALARM    UNIT 182
08/25/95 10:39:49 LIMIT  414 ENG TMR   420.   ENGINE FAILED ALARM     UNIT 182
¿ESTART AT: 08/25/95 12:53:30 (08/25/95 10:41:12) S5245  V2.23 .
08/25/95 12:53:33  UNIT 182
100     0.     94.F    79.F   104.F    2.  -25.0  -25.0     0.  -392.    0.0    0.1  0.700   0.00    7   116   45.
08/25/95 12:54:11  UNIT 182
100     4.     94.F    79.F   104.F    0.   14.1   -0.1     0.     0.   12.2   31.7  0.637   0.00    7   116   45.
08/25/95 12:55:25  UNIT 182         Start SlurPING ~1300HRS
100     4.     94.F    79.F   105.F    0.   22.1   -0.0     0.     0.   12.3   99.9  0.500   0.00    7   116   45.
08/25/95 13:08:07 LIMIT  414 ENG TMR   714.   ENGINE FAILED ALARM     UNIT 182
¿ESTART AT: 08/25/95 13:14:43 (08/25/95 13:12:04) S5245  V2.23 .
08/25/95 13:14:46  UNIT 182
100     0.    179.F   130.F   425.F    0.  -25.0  -25.0     0.  -395.   -0.0    0.1  0.700   0.00    7   137   45.
¿ESTART AT: 08/25/95 13:23:06 (08/25/95 13:17:37) S5245  V2.23 .
08/25/95 13:23:09 LIMIT   110 BATTERY      0.0   LOW BATT. VOLT ALARM     UNIT 182
08/25/95 13:23:09 LIMIT   414 ENG TMR    165.    ENGINE FAILED ALARM      UNIT 182
08/25/95 13:23:09  UNIT 182
100     0.    179.F   136.F   455.F   61.  -25.0  -25.0     0.  -395.    0.0    0.1  0.700   1.71    7   142   45.
08/25/95 13:30:00  UNIT 182
100  2358.    164.F   175.F  1012.F   52.   -0.3   18.5   140.   -3.   13.7   53.0  0.594   1.14    7   150   45.
08/25/95 13:32:16  UNIT 182
100  2358.    166.F   177.F  1028.F   52.   -0.3   18.5   139.   -3.   13.7   52.9  0.594   1.19    7   153   45.
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100	2240.	165.F	176.F	1005.F	52.	-0.3	15.7	126.	-0.	13.7	54.7	0.591	1.13	7	163	45.
08/25/95 13:49:58 UNIT 182																
100	2134.	163.F	175.F	983.F	52.	-0.3	13.9	119.	0.	13.7	56.8	0.586	0.99	7	172	45.
08/25/95 13:59:24 UNIT 182																
100	2133.	163.F	177.F	981.F	52.	-0.3	13.8	119.	-1.	13.6	59.1	0.582	1.07	7	182	45.
08/25/95 14:00:00 UNIT 182																
100	2115.	161.F	176.F	979.F	52.	-0.3	13.8	119.	-1.	13.6	57.5	0.585	1.07	7	183	45.
08/25/95 14:00:29 UNIT 182																
100	2331.	161.F	176.F	980.F	52.	-0.3	17.7	136.	-2.	13.6	56.3	0.587	1.08	7	184	45.
08/25/95 14:01:49 UNIT 182																
100	2351.	162.F	176.F	1008.F	52.	-0.3	17.8	136.	-1.	13.7	55.3	0.589	1.38	7	186	45.
08/25/95 14:30:00 UNIT 182																
100	2158.	161.F	176.F	976.F	52.	-0.3	14.0	120.	-1.	13.7	59.0	0.582	1.18	7	219	46.
08/25/95 15:00:00 UNIT 182																
100	2130.	170.F	179.F	993.F	52.	-0.4	14.0	120. cfm	-2.	13.5	61.2	0.578	1.10 cfm	7	254	46.
08/25/95 15:30:00 UNIT 182																
100	2148.	168.F	179.F	995.F	52.	-0.4	14.4	121.	-2.	13.5	62.6	0.575	1.35	7	294	47.
08/25/95 15:45:04 UNIT 182																
100	2143.	163.F	177.F	988.F	52.	-0.4	14.4	121.	-1.	13.5	61.2	0.578	1.22	7	314	47.

40 cu ft.

20 cu ft

Flow measurement going into ICE unit

Cfm PROPANE

PROPANE usage

V.R.SYSTEMS INC.

MODEL V3 S/N 182
PERMIT NO.

ENGINE RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	VAC.H20	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	UNITS	ENGINE HOURS
08/25/95 16:00:00 UNIT 182															
100 2199.	172.F	180.F	990.F	52.	-0.4	14.3	121.	-2.	13.4	61.8	0.576	1.44	7	336	47.
08/25/95 16:30:00 UNIT 182															

08/25/95 17:00:00 UNIT 182																
100	2132.	168.F	179.F	973.F	52.	-0.4	13.2	117.	0.	13.4	60.2	0.580	1.29	7	421	48.
08/25/95 17:30:00 UNIT 182																
100	2140.	163.F	174.F	951.F	52.	-0.3	12.9	116.	1.	13.7	57.7	0.585	1.32	7	463	49.
08/25/95 17:53:22 UNIT 182																
100	2126.	165.F	177.F	966.F	52.	-0.4	12.9	116.	0.	13.6	59.7	0.581	1.33	7	495	49.
08/25/95 18:00:00 UNIT 182																
100	2128.	165.F	176.F	964.F	52.	-0.4	12.7	116.	1.	13.5	60.2	0.580	1.33	7	504	49.
08/25/95 18:30:00 UNIT 182																
100	2137.	169.F	180.F	972.F	52.	-0.4	13.0	117.	-0.	13.4	63.6	0.573	1.38	7	547	50.
08/25/95 19:00:00 UNIT 182																
100	2142.	163.F	171.F	954.F	52.	-0.3	13.1	117.	-1.	13.9	54.1	0.592	1.41	7	591	50.
08/25/95 19:30:00 UNIT 182																
100	2163.	163.F	171.F	958.F	52.	-0.3	13.1	117.	-1.	13.8	53.2	0.594	1.46	7	635	51.
08/25/95 20:00:00 UNIT 182																
100	2163.	163.F	171.F	960.F	52.	-0.3	13.1	117.	-1.	13.8	52.8	0.594	1.47	7	680	51.
08/25/95 20:30:00 UNIT 182																
100	2154.	163.F	171.F	959.F	52.	-0.3	13.0	116.	-1.	13.8	53.5	0.593	1.46	7	726	52.
08/25/95 21:00:00 UNIT 182																
100	2145.	161.F	169.F	954.F	52.	-0.3	12.9	116.	-1.	13.8	51.9	0.596	1.45	7	771	52.
08/25/95 21:30:00 UNIT 182																
100	2145.	162.F	171.F	956.F	52.	-0.3	12.8	115.	-1.	13.7	52.4	0.595	1.44	7	817	53.
08/25/95 22:00:00 UNIT 182																
100	2149.	163.F	172.F	955.F	52.	-0.3	12.7	115.	1.	13.7	52.7	0.595	1.45	7	862	53.
08/25/95 22:30:00 UNIT 182																
100	2118.	165.F	175.F	957.F	52.	-0.3	12.5	114.	2.	13.6	53.7	0.593	1.45	7	907	54.
08/25/95 23:00:00 UNIT 182																
100	2117.	165.F	175.F	956.F	52.	-0.3	12.4	114.	2.	13.7	55.3	0.589	1.46	7	952	54.
08/25/95 23:30:00 UNIT 182																
100	2137.	164.F	175.F	956.F	52.	-0.3	12.4	114.	2.	13.7	54.7	0.591	1.46	7	998	55.
08/26/95 00:00:00 UNIT 182																
100	2118.	164.F	174.F	956.F	52.	-0.3	12.4	114.	2.	13.7	53.6	0.593	1.47	8	44	55.
08/26/95 00:30:00 UNIT 182																
100	2122.	165.F	175.F	956.F	52.	-0.3	12.4	114.	2.	13.7	53.9	0.592	1.47	8	89	56.
08/26/95 01:00:00 UNIT 182																
100	2110.	165.F	174.F	955.F	52.	-0.3	12.4	114.	2.	13.7	52.7	0.595	1.49	8	136	56.
08/26/95 01:30:00 UNIT 182																
100	2130.	165.F	174.F	955.F	52.	-0.3	12.4	114.	2.	13.7	55.1	0.590	1.51	8	182	57.
08/26/95 02:00:00 UNIT 182																
100	2116.	164.F	174.F	956.F	52.	-0.3	12.4	114.	2.	13.7	52.6	0.595	1.45	8	228	57.
08/26/95 02:30:00 UNIT 182																
100	2136.	164.F	173.F	957.F	52.	-0.3	12.4	114.	2.	13.7	54.2	0.592	1.49	8	274	58.
08/26/95 03:00:00 UNIT 182																
100	2132.	164.F	174.F	957.F	52.	-0.3	12.4	114.	2.	13.7	54.3	0.591	1.50	8	321	58.
08/26/95 03:30:00 UNIT 182																
100	2139.	164.F	174.F	957.F	52.	-0.3	12.4	114.	2.	13.7	53.9	0.592	1.50	8	367	59.
08/26/95 04:00:00 UNIT 182																
100	2119.	164.F	173.F	958.F	52.	-0.3	12.4	114.	2.	13.7	54.2	0.592	1.51	8	414	59.
08/26/95 04:30:00 UNIT 182																
100	2112.	164.F	172.F	957.F	52.	-0.3	12.4	114.	2.	13.8	51.1	0.598	1.50	8	461	60.
08/26/95 05:00:00 UNIT 182																
100	2132.	163.F	170.F	954.F	52.	-0.3	12.5	114.	1.	13.8	49.5	0.601	1.50	8	508	60.

V.R.SYSTEMS INC. MODEL V3 S/N 182
PERMIT NO.

ENGINE RPM		TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	-VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	-UNITS	ENGINE HOURS
08/26/95 05:30:00 UNIT 182																
100	2118.	163.F	170.F	953.F	52.	-0.3	12.5	114.	1.	13.8	49.1	0.602	1.49	8	554	61.
08/26/95 06:00:00 UNIT 182																

08/26/95 06:30:00 UNIT 182

100 2133. 162.F 170.F 952.F 52. -0.3 12.4 114. 1. 13.8 51.2 0.598 1.48 8 647 62.

08/26/95 07:00:00 UNIT 182

100 2114. 163.F 171.F 954.F 52. -0.3 12.4 114. 1. 13.8 51.5 0.597 1.50 8 693 62.

08/26/95 07:30:00 UNIT 182

100 2144. 163.F 171.F 957.F 52. -0.3 12.5 115. 1. 13.7 52.2 0.596 1.49 8 740 63.

08/26/95 08:00:00 UNIT 182

100 2130. 163.F 174.F 960.F 52. -0.3 12.7 116. 2. 13.7 52.6 0.595 1.52 8 787 63.

08/26/95 08:11:40 LIMIT 414 ENG TMR OVRNG ENGINE FAILED ALARM UNIT 182

08/26/95 08:13:31 UNIT 182

100 12. 178.F 154.F 664.F 0. 12.1 16.3 0. 3. 12.3 21.3 0.657 0.00 8 798 64.

¿ESTART AT: 08/26/95 08:27:06 (08/26/95 08:17:02) S5245 V2.23 .

08/26/95 08:27:09 UNIT 182

100 0. 165.F 137.F 327.F 2. -25.0 -25.0 0. -392. 0.0 0.1 0.700 0.00 8 798 64.

¿ESTART AT: 08/26/95 08:29:53 (08/26/95 08:27:24) S5245 V2.23 .

08/26/95 08:29:56 UNIT 182

100 3. 162.F 134.F 294.F 100. 23.3 -0.3 0. -0. 12.8 99.4 0.501 0.00 8 799 64.

08/26/95 08:39:44 UNIT 182

100 2204. 163.F 175.F 992.F 52. 10.7 6.5 83. -0. 13.9 50.8 0.598 1.51 8 815 64.

08/26/95 08:44:17 UNIT 182

100 2161. 162.F 172.F 980.F 52. -0.3 13.1 116. -1. 13.9 52.1 0.596 1.46 8 822 64.

08/26/95 09:00:00 UNIT 182

100 2139. 162.F 171.F 974.F 52. -0.3 13.1 116. -1. 13.8 51.7 0.597 1.47 8 846 64.

08/26/95 09:30:00 UNIT 182

100 2138. 162.F 171.F 961.F 52. -0.3 13.0 116. -1. 13.8 49.5 0.601 1.45 8 891 65.

08/26/95 10:00:00 UNIT 182

100 2124. 163.F 171.F 960.F 52. -0.3 13.0 115. -1. 13.8 49.4 0.601 1.41 8 935 65.

08/26/95 10:12:49 UNIT 182

100 2232. 163.F 172.F 964.F 52. -0.3 14.9 122. -1. 13.9 48.1 0.604 1.45 8 953 65.

08/26/95 10:14:00 UNIT 182

100 2096. 163.F 172.F 960.F 52. -0.3 12.1 113. -0. 13.8 50.4 0.599 1.46 8 955 65.

08/26/95 10:30:00 UNIT 182

100- 2085. 163.F 171.F 953.F 52. -0.3 12.1 113. -1. 13.8 51.0 0.598 1.33 8 977 66.

08/26/95 11:00:00 UNIT 182

100 2049. 163.F 170.F 933.F 52. -0.3 11.7 111. -0. 14.0 51.2 0.598 1.29 9 18 66.

08/26/95 11:30:00 UNIT 182

100 2050. 163.F 170.F 934.F 52. -0.3 11.7 111. -0. 14.0 49.5 0.601 1.29 9 58 67.

08/26/95 12:00:00 UNIT 182

100 2042. 163.F 171.F 935.F 53. -0.3 11.7 111. -0. 13.9 49.5 0.601 1.30 9 99 67.

08/26/95 12:30:00 UNIT 182

100 2036. 163.F 171.F 932.F 52. -0.3 11.7 111. -1. 13.9 50.3 0.599 1.29 9 139 68.

08/26/95 13:00:00 UNIT 182

100 2033. 163.F 171.F 934.F 52. -0.3 11.7 112. -1. 13.9 50.1 0.600 1.26 9 179 68.

08/26/95 13:30:00 UNIT 182

100 2027. 163.F 171.F 931.F 52. -0.3 11.7 112. -1. 13.9 50.1 0.600 1.28 9 219 69.

08/26/95 14:00:00 UNIT 182

100 2032. 163.F 171.F 931.F 52. -0.3 11.7 111. -1. 14.0 50.2 0.600 1.30 9 259 69.

08/26/95 14:30:00 UNIT 182

100 2031. 163.F 171.F 929.F 52. -0.3 11.7 111. -1. 14.0 48.6 0.603 1.30 9 300 70.

08/26/95 15:00:00 UNIT 182

100 2031. 163.F 171.F 932.F 52. -0.3 11.7 111. -1. 14.0 49.2 0.602 1.30 9 341 70.

V.R.SYSTEMS INC.　　　　MODEL V3 S/N 182
PERMIT NO.

ENGINE	RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	UNITS	ENGINE HOURS
08/26/95 15:30:00 UNIT 182																
100	2027.	163.F	171.F	928.F	52.	-0.3	11.7	112.	-1.	14.0	48.8	0.602	1.30	9	381	71.
08/26/95 16:00:00 UNIT 182																
100	2048.	162.F	170.F	927.F	52.	-0.3	11.7	111.	-1.	14.0	49.2	0.602	1.27	9	422	71.
08/26/95 16:30:00 UNIT 182																
100	2041.	162.F	170.F	926.F	52.	-0.3	11.7	111.	-1.	14.0	49.4	0.601	1.30	9	462	72.
08/26/95 17:00:00 UNIT 182																
100	2056.	162.F	170.F	929.F	52.	-0.3	11.7	111.	-2.	14.0	50.3	0.599	1.32	9	504	72.
08/26/95 17:30:00 UNIT 182																
100	2055.	162.F	170.F	928.F	52.	-0.3	11.7	111.	-1.	14.1	50.6	0.599	1.30	9	545	73.
08/26/95 18:00:00 UNIT 182																
100	2042.	162.F	169.F	924.F	52.	-0.3	11.7	112.	-2.	14.1	49.8	0.600	1.32	9	586	73.
08/26/95 18:30:00 UNIT 182																
100	2033.	162.F	169.F	930.F	52.	-0.3	11.7	112.	-2.	14.0	48.7	0.603	1.32	9	627	74.
08/26/95 18:55:18 UNIT 182																
100	2050.	162.F	169.F	932.F	52.	-0.3	11.7	111.	-2.	14.0	48.9	0.602	1.29	9	662	74.
08/26/95 19:00:00 UNIT 182																
100	2134.	163.F	172.F	964.F	52.	-0.3	13.6	118.	-2.	13.9	49.1	0.602	1.49	9	669	74.
08/26/95 19:27:23 UNIT 182																
100	2078.	163.F	173.F	950.F	52.	8.8	5.2	77.	1.	13.9	48.3	0.603	1.44	9	711	75.
08/26/95 19:28:15 UNIT 182																
100	2089.	163.F	173.F	948.F	52.	13.1	-0.2	58.	2.	13.9	47.8	0.604	1.44	9	713	75.
08/26/95 19:29:44 UNIT 182																
100	2464.	164.F	173.F	962.F	52.	21.1	-0.3	48.	2.	14.0	46.0	0.608	1.65	9	715	75.
08/26/95 19:30:00 UNIT 182																
100	2564.	165.F	173.F	980.F	52.	23.3	-0.3	46.	2.	13.9	47.8	0.604	1.93	9	716	75.
08/26/95 19:30:58 UNIT 182																
100	2049.	164.F	175.F	993.F	52.	13.0	-0.3	57.	2.	14.0	49.2	0.602	1.95	9	718	75.
08/26/95 19:31:26 UNIT 182																
100	1871.	164.F	174.F	960.F	52.	10.0	-0.3	59.	2.	14.0	50.8	0.598	1.58	9	718	75.
08/26/95 19:51:36 UNIT 182																
100	2173.	164.F	170.F	947.F	52.	14.9	1.7	63.	1.	14.0	49.8	0.600	1.52	9	759	75.
08/26/95 19:54:38 UNIT 182																
100	2151.	164.F	171.F	969.F	52.	-0.3	14.1	119.	-1.	14.0	50.7	0.599	1.24	9	763	75.
08/26/95 20:00:00 UNIT 182																
100	2153.	164.F	172.F	976.F	52.	-0.3	14.1	120.	-0.	13.9	49.4	0.601	1.30	9	770	75.
08/26/95 21:00:00 UNIT 182																
100	2139.	166.F	177.F	974.F	52.	-0.4	13.6	118.	1.	13.6	52.0	0.596	1.60	9	867	76.
08/26/95 22:00:00 UNIT 182																
100	2114.	165.F	175.F	971.F	52.	-0.4	13.5	117.	1.	13.7	50.2	0.600	1.59	9	968	77.
08/26/95 23:00:00 UNIT 182																
100	2121.	165.F	176.F	973.F	52.	-0.4	13.5	117.	1.	13.7	51.7	0.597	1.63	10	68	78.
08/27/95 00:00:00 UNIT 182																
100	2114.	166.F	176.F	975.F	52.	-0.4	13.4	117.	1.	13.6	53.2	0.594	1.66	10	169	79.
08/27/95 01:00:00 UNIT 182																
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

08/27/95 02:00:00 UNIT 182																
100	2124.	165.F	177.F	974.F	52.	-0.4	13.4	117.	1.	13.7	53.0	0.594	1.67	10	376	81.
08/27/95 03:00:00 UNIT 182																
100	2135.	166.F	177.F	973.F	52.	-0.4	13.4	117.	1.	13.7	51.2	0.598	1.68	10	481	82.
08/27/95 04:00:00 UNIT 182																
100	2110.	166.F	177.F	973.F	52.	-0.4	13.4	117.	1.	13.6	50.4	0.599	1.70	10	586	83.
08/27/95 05:00:00 UNIT 182																
100	2117.	166.F	177.F	975.F	52.	-0.4	13.4	118.	0.	13.7	52.2	0.596	1.71	10	692	84.
08/27/95 06:00:00 UNIT 182																
100	2123.	166.F	178.F	979.F	52.	-0.4	13.7	117.	1.	13.6	51.3	0.597	1.75	10	799	85.

V.R.SYSTEMS INC.

MODEL V3 S/N 182
PERMIT NO.

ENGINE		TEMPERATURE			OIL	POSITIONS		WELL FLOW		BATTERY	DUTY	PERCENT	AUXILIARY FUEL			ENGINE
	RPM	COOLANT	OIL	EXHAUST	PSI	CARB.	BYPASS	CFM-	VAC.H2O	VOLTS	CYCLE	OXYGEN	CFM	THOUSANDS-	UNITS	HOURS
08/27/95 07:00:00 UNIT 182																
100	2156.	165.F	177.F	947.F	52.	-0.4	12.6	114.	0.	13.7	50.2	0.600	2.69	10	943	86.
08/27/95 07:40:05 UNIT 182																
100	2101.	164.F	175.F	936.F	52.	12.4	-0.3	57.	2.	13.8	49.7	0.601	2.59	11	52	87.
08/27/95 08:00:00 UNIT 182																
100	2137.	163.F	167.F	852.F	52.	22.1	-0.5	0.	1.	13.8	51.0	0.598	2.19	11	95	87.
08/27/95 08:01:35 UNIT 182																
100	2090.	164.F	170.F	926.F	52.	22.6	10.9	0.	2.	13.9	45.6	0.609	2.62	11	99	87.
08/27/95 08:02:17 UNIT 182																
100	2182.	164.F	170.F	932.F	52.	22.8	18.7	0.	1.	13.9	52.4	0.595	2.61	11	101	87.
08/27/95 08:03:24 UNIT 182																
100	2672.	166.F	172.F	972.F	52.	17.0	23.5	116.	-2.	13.9	47.2	0.606	2.06	11	103	87.
08/27/95 08:04:28 UNIT 182																
100	2639.	168.F	177.F	1050.F	52.	5.4	23.6	152.	-3.	13.9	48.7	0.603	1.83	11	105	87.
08/27/95 08:05:19 UNIT 182																
100	2443.	168.F	180.F	1058.F	52.	-0.3	19.8	144.	-2.	13.9	51.8	0.596	1.99	11	107	87.
08/27/95 08:06:53 UNIT 182																
100	2129.	165.F	178.F	1002.F	52.	-0.3	13.2	116.	-0.	13.8	52.6	0.595	1.34	11	109	87.
08/27/95 09:00:00 UNIT 182																
100	2126.	164.F	173.F	973.F	52.	-0.3	13.2	116.	-3.	13.7	52.5	0.595	1.63	11	196	88.
08/27/95 10:00:00 UNIT 182																
100	2111.	165.F	175.F	983.F	52.	-0.3	13.4	117.	-3.	13.6	54.9	0.590	1.67	11	299	89.
08/27/95 11:00:00 UNIT 182																
100	2115.	166.F	177.F	980.F	52.	-0.3	13.6	118.	-3.	13.6	55.5	0.589	1.69	11	403	90.
08/27/95 12:00:00 UNIT 182																
100	2121.	168.F	179.F	991.F	52.	-0.3	14.0	119.	-4.	13.5	55.9	0.588	1.75	11	510	91.
08/27/95 13:00:00 UNIT 182																
100	2116.	165.F	176.F	973.F	52.	-0.3	14.1	120.	-2.	13.7	51.2	0.598	1.71	11	617	92.
08/27/95 13:18:16 UNIT 182																
100	2137.	165.F	175.F	974.F	52.	-0.3	14.1	120.	-2.	13.9	51.5	0.597	1.72	11	649	92.
08/27/95 14:00:00 UNIT 182																
100	2129.	165.F	175.F	971.F	52.	-0.3	14.1	120.	-3.	13.9	51.0	0.598	1.72	11	723	93.
08/27/95 15:00:00 UNIT 182																
100	2140.	165.F	175.F	970.F	52.	-0.3	14.1	120.	-2.	13.9	52.7	0.595	1.72	11	830	94.
08/27/95 16:00:00 UNIT 182																
100	2150.	164.F	174.F	969.F	52.	-0.3	14.1	119.	-3.	13.9	51.0	0.598	1.71	11	937	95.
08/27/95 17:00:00 UNIT 182																
100	2145.	165.F	174.F	968.F	52.	-0.3	14.1	119.	-3.	13.9	50.8	0.598	1.73	12	44	96.
08/27/95 18:00:00 UNIT 182																
100	2165.	164.F	174.F	968.F	52.	-0.3	14.0	119.	-3.	13.9	50.3	0.599	1.72	12	152	97.
08/27/95 18:16:47 UNIT 182																
100	2150.	164.F	174.F	968.F	52.	-0.3	14.0	119.	-3.	13.9	49.4	0.601	1.74	12	182	97.
08/27/95 19:00:00 UNIT 182																
100	2147.	164.F	173.F	969.F	52.	-0.3	14.0	119.	-1.	13.9	49.0	0.602	1.76	12	259	98.
08/27/95 20:00:00 UNIT 182																

Date/Time	Unit																
08/27/95 21:00:00	UNIT 182	100	2134.	164.F	174.F	973.F	52.	-0.3	13.9	119.	-1.	13.8	50.1	0.600	1.76	12	476	100.
08/27/95 21:25:41	UNIT 182	100	2130.	163.F	172.F	970.F	53.	-0.3	13.9	118.	-1.	13.9	49.8	0.600	1.74	12	522	101.
08/27/95 22:00:00	UNIT 182	100	2131.	165.F	175.F	964.F	52.	-0.3	13.8	118.	-0.	13.7	50.5	0.599	1.75	12	584	101.
08/27/95 23:00:00	UNIT 182	100	2117.	166.F	177.F	965.F	52.	-0.3	13.7	118.	0.	13.6	51.1	0.598	1.75	12	691	102.
08/28/95 00:00:00	UNIT 182	100	2116.	165.F	176.F	971.F	52.	-0.3	13.9	119.	0.	13.7	52.2	0.596	1.76	12	800	103.

V.R.SYSTEMS INC.

MODEL V3 S/N 182
PERMIT NO.

Date/Time	Unit		ENGINE RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	UNITS	ENGINE HOURS
08/28/95 01:00:00	UNIT 182	100	2106.	166.F	177.F	973.F	52.	-0.3	13.9	119.	-0.	13.5	52.7	0.595	1.77	12	909	104.
08/28/95 02:00:00	UNIT 182	100	2133.	165.F	177.F	974.F	52.	-0.3	14.0	119.	0.	13.6	53.4	0.593	1.76	13	19	105.
08/28/95 03:00:00	UNIT 182	100	2131.	164.F	175.F	972.F	52.	-0.3	14.0	119.	-0.	13.9	48.0	0.604	1.76	13	128	106.
08/28/95 04:00:00	UNIT 182	100	2143.	164.F	174.F	969.F	52.	-0.3	14.0	119.	-1.	13.9	48.2	0.604	1.74	13	237	107.
08/28/95 05:00:00	UNIT 182	100	2155.	164.F	173.F	967.F	52.	-0.3	14.0	119.	-0.	13.9	48.5	0.603	1.72	13	345	108.
08/28/95 06:00:00	UNIT 182	100	2139.	164.F	173.F	970.F	52.	-0.3	14.0	119.	-0.	13.9	47.9	0.604	1.77	13	453	109.
08/28/95 07:00:00	UNIT 182	100	2145.	164.F	173.F	968.F	52.	-0.3	14.0	119.	-0.	13.9	47.1	0.606	1.72	13	561	110.
08/28/95 07:31:49	UNIT 182	100	2003.	163.F	170.F	918.F	52.	10.9	1.8	64.	2.	13.8	48.1	0.604	1.49	13	617	111.
08/28/95 07:32:20	UNIT 182	100	2020.	163.F	169.F	918.F	52.	12.4	-0.4	57.	2.	14.0	50.1	0.600	1.51	13	617	111.
08/28/95 07:33:33	UNIT 182	100	1841.	163.F	169.F	916.F	52.	10.3	-0.4	59.	2.	14.0	50.1	0.600	1.47	13	619	111.
08/28/95 07:52:14	UNIT 182	100	2194.	164.F	170.F	948.F	52.	12.3	5.8	78.	0.	14.0	47.8	0.604	1.31	13	658	111.
08/28/95 07:53:59	UNIT 182	100	2208.	164.F	171.F	961.F	53.	0.8	14.7	121.	-2.	13.9	49.5	0.601	1.50	13	660	111.
08/28/95 08:00:00	UNIT 182	100	2048.	162.F	170.F	935.F	52.	-0.2	12.2	113.	-0.	14.0	47.7	0.605	1.60	13	670	111.
08/28/95 08:44:05	UNIT 182	100	2046.	163.F	169.F	926.F	52.	-0.3	11.8	112.	-1.	14.0	47.0	0.606	1.53	13	741	112.
08/28/95 09:00:00	UNIT 182	100	2052.	163.F	170.F	926.F	52.	-0.3	11.8	112.	-1.	14.0	49.8	0.600	1.51	13	766	112.
08/28/95 10:00:00	UNIT 182	100	2039.	163.F	169.F	929.F	52.	-0.3	11.8	112.	-1.	14.0	50.1	0.600	1.52	13	861	113.
08/28/95 11:00:00	UNIT 182	100	2028.	163.F	170.F	926.F	52.	-0.3	11.8	112.	-1.	14.0	48.0	0.604	1.53	13	956	114.
08/28/95 12:00:00	UNIT 182	100	2032.	163.F	171.F	929.F	52.	-0.3	11.8	113.	-1.	13.9	48.7	0.603	1.52	14	51	115.
08/28/95 13:00:00	UNIT 182	100	2013.	164.F	172.F	930.F	52.	-0.3	11.8	112.	-0.	13.9	47.9	0.604	1.54	14	145	116.
08/28/95 13:58:13	UNIT 182	100	2028.	165.F	172.F	926.F	52.	-0.3	11.8	112.	-1.	13.9	51.0	0.598	1.54	14	237	117.
08/28/95 14:00:00	UNIT 182	100	2019.	164.F	172.F	926.F	52.	-0.3	11.8	113.	-1.	13.9	51.6	0.597	1.49	14	240	117.
08/28/95 15:00:00	UNIT 182	100	2066.	163.F	173.F	895.F	52.	-0.3	10.2	107.	-1.	13.9	49.5	0.601	2.45	14	354	118.
08/28/95 15:08:57	UNIT 182																	

08/28/95 15:10:16 UNIT 182																
100	1910.	163.F	171.F	880.F	52.	9.2	-0.3	59.	1.	14.0	47.8	0.604	2.36	14	379	118.
08/28/95 15:13:55 UNIT 182																
100	2127.	163.F	169.F	843.F	52.	21.6	-0.5	0.	2.	14.0	48.6	0.603	2.33	14	387	118.
08/28/95 15:16:34 UNIT 182																
100	2203.	165.F	173.F	961.F	52.	12.9	5.7	77.	-0.	13.9	50.7	0.599	0.89	14	390	118.
08/28/95 15:22:11 UNIT 182																
100	2069.	164.F	173.F	943.F	52.	-0.2	12.6	115.	-1.	14.0	51.7	0.597	1.46	14	397	118.
08/28/95 16:00:00 UNIT 182																
100	2061.	163.F	172.F	935.F	52.	-0.2	12.3	114.	-1.	13.9	49.4	0.601	1.56	14	458	119.

V.R.SYSTEMS INC. MODEL V3 S/N 182
PERMIT NO.

ENGINE		TEMPERATURE			OIL	POSITIONS		WELL FLOW		BATTERY	DUTY	PERCENT	AUXILIARY FUEL			ENGINE
	RPM	COOLANT	OIL	EXHAUST	PSI	CARB.	BYPASS	CFM-	VAC.H2O	VOLTS	CYCLE	OXYGEN	CFM	THOUSANDS-	UNITS	HOURS
08/28/95 17:00:00 UNIT 182																
100	2055.	164.F	173.F	930.F	52.	-0.2	12.3	114.	-0.	13.9	49.5	0.601	1.56	14	554	120.
08/28/95 18:00:00 UNIT 182																
100	2042.	163.F	172.F	933.F	52.	-0.2	12.3	114.	-0.	14.0	50.8	0.598	1.57	14	652	121.
08/28/95 19:00:00 UNIT 182																
100	2063.	162.F	170.F	929.F	52.	-0.2	12.0	113.	-1.	14.0	50.0	0.600	1.56	14	750	122.
08/28/95 20:00:00 UNIT 182																
100	2059.	163.F	173.F	937.F	52.	-0.3	11.9	113.	1.	13.7	49.5	0.601	1.61	14	850	123.
08/28/95 21:00:00 UNIT 182																
100	2039.	163.F	171.F	935.F	52.	-0.2	11.9	112.	0.	13.8	47.4	0.605	1.60	14	949	124.
08/28/95 22:00:00 UNIT 182																
100	2036.	164.F	171.F	936.F	52.	-0.2	11.9	112.	0.	13.8	48.9	0.602	1.62	15	49	125.
08/28/95 23:00:00 UNIT 182																
100	2049.	163.F	172.F	935.F	52.	-0.2	11.8	112.	1.	13.7	49.9	0.600	1.61	15	150	126.
08/29/95 00:00:00 UNIT 182																
100	2036.	163.F	172.F	935.F	52.	-0.2	11.8	112.	1.	13.7	48.7	0.603	1.62	15	250	127.
08/29/95 01:00:00 UNIT 182																
100	2023.	163.F	174.F	935.F	52.	-0.3	11.7	112.	1.	13.6	52.9	0.594	1.58	15	350	128.
08/29/95 02:00:00 UNIT 182																
100	2038.	164.F	173.F	936.F	52.	-0.3	11.7	111.	1.	13.6	50.1	0.600	1.61	15	450	129.
08/29/95 03:00:00 UNIT 182																
100	2048.	164.F	171.F	934.F	52.	-0.3	11.7	112.	0.	13.7	50.9	0.598	1.62	15	550	130.
08/29/95 04:00:00 UNIT 182																
100	2035.	164.F	174.F	934.F	52.	-0.3	11.7	112.	0.	13.6	52.2	0.596	1.61	15	650	131.
08/29/95 05:00:00 UNIT 182																
100	2039.	165.F	174.F	931.F	52.	-0.3	11.6	111.	1.	13.6	51.8	0.596	1.62	15	750	132.
08/29/95 06:00:00 UNIT 182																
100	2044.	164.F	172.F	937.F	52.	-0.3	11.7	112.	0.	13.6	51.3	0.597	1.63	15	850	133.
08/29/95 07:00:00 UNIT 182 — Stop SLURPING test 0700																
100	2083.	161.F	169.F	912.F	52.	-0.3	10.3	106.	-0.	13.9	49.0	0.602	2.48	15	956	134.
08/29/95 07:06:34 UNIT 182																
100	1972.	161.F	168.F	893.F	52.	4.2	5.4	81.	0.	13.9	46.2	0.608	2.33	15	972	134.
08/29/95 07:07:22 UNIT 182																
100	1766.	161.F	168.F	889.F	52.	3.6	2.6	70.	1.	13.9	47.7	0.605	2.29	15	974	134.
08/29/95 07:51:46 UNIT 182 START Skimming (2) test·0750																
100	2146.	159.F	165.F	872.F	52.	22.0	-0.5	0.	0.	14.0	49.6	0.601	2.47	16	71	135.
08/29/95 07:52:33 UNIT 182																
100	2148.	160.F	165.F	899.F	52.	22.0	5.5	0.	0.	14.0	50.5	0.599	2.64	16	74	135.
08/29/95 07:53:54 UNIT 182																
100	2463.	164.F	167.F	936.F	52.	19.6	9.0	61.	-1.	13.8	49.1	0.602	2.48	16	77	135.
08/29/95 07:54:42 UNIT 182																
100	2257.	162.F	169.F	973.F	52.	10.9	9.0	91.	-1.	14.0	52.4	0.595	1.90	16	078	135.
08/29/95 08:00:00 UNIT 182																
100	2140.	161.F	169.F	967.F	52.	-0.2	14.1	119.	-2.	13.9	49.6	0.601	1.20	16	084	135.
08/29/95 08:25:53 UNIT 182																

08/29/95 08:30:00 UNIT 182																
100	1996.	161.F	170.F	971.F	52.	-0.2	13.3	116.	-2.	13.7	52.4	0.595	1.42	16	132	136.
08/29/95 09:00:00 UNIT 182																
100	2003.	163.F	172.F	991.F	52.	-0.3	14.3	120.	-3.	13.7	53.0	0.594	1.51	16	178	136.
08/29/95 09:30:00 UNIT 182																
100	2005.	164.F	173.F	1006.F	52.	-0.3	15.0	122.	-3.	13.6	55.7	0.589	1.59	16	226	137.
08/29/95 10:00:00 UNIT 182																
100	2019.	165.F	174.F	999.F	52.	-0.3	15.4	125.	-4.	13.4	54.4	0.591	1.59	16	275	137.
08/29/95 10:30:00 UNIT 182																
100	2043.	164.F	171.F	1000.F	52.	-0.3	15.5	124.	-3.	13.8	52.1	0.596	1.58	16	325	138.

V.R.SYSTEMS INC. MODEL V3 S/N 182
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ENGINE	RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	-VAC.H20	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	-UNITS	ENGINE HOURS
08/29/95 11:00:00 UNIT 182																
100	2012.	165.F	174.F	1014.F	52.	-0.3	15.7	125.	-3.	13.6	56.3	0.587	1.58	16	374	138.
08/29/95 11:30:00 UNIT 182																
100	2006.	167.F	173.F	1010.F	52.	-0.3	15.7	125.	-3.	13.7	54.6	0.591	1.57	16	423	139.
08/29/95 12:00:00 UNIT 182																
100	2005.	163.F	174.F	1008.F	52.	-0.3	16.0	126.	-3.	13.6	54.7	0.591	1.59	16	472	139.
08/29/95 12:30:00 UNIT 182																
100	2019.	171.F	178.F	1022.F	52.	-0.4	16.2	127.	-3.	13.5	59.0	0.582	1.58	16	521	140.
08/29/95 13:00:00 UNIT 182																
100	2030.	169.F	178.F	1022.F	52.	-0.4	16.4	128.	-3.	13.5	56.3	0.587	1.59	16	571	140.
08/29/95 13:30:00 UNIT 182																
100	2016.	165.F	176.F	1021.F	52.	-0.4	16.4	127.	-3.	13.6	57.4	0.585	1.58	16	620	141.
08/29/95 14:00:00 UNIT 182																
100	2029.	165.F	176.F	1019.F	52.	-0.4	16.6	128.	-3.	13.6	59.0	0.582	1.60	16	670	141.
08/29/95 14:30:00 UNIT 182																
100	2043.	169.F	179.F	1021.F	52.	-0.4	16.6	128.	-3.	13.5	60.8	0.578	1.62	16	720	142.
08/29/95 14:43:31 UNIT 182																
100	2021.	173.F	179.F	1025.F	52.	-0.4	16.5	128.	-3.	13.5	57.6	0.585	1.60	16	742	142.
08/29/95 15:00:00 UNIT 182																
100	2022.	166.F	176.F	1021.F	52.	-0.4	16.7	129.	-3.	13.6	58.0	0.584	1.58	16	768	142.
08/29/95 15:30:00 UNIT 182																
100	2025.	174.F	181.F	1026.F	52.	-0.4	16.6	129.	-3.	13.4	59.4	0.581	1.57	16	817	143.
08/29/95 16:00:00 UNIT 182																
100	2014.	168.F	177.F	1023.F	52.	-0.4	16.7	129.	-3.	13.6	56.5	0.587	1.58	16	866	143.
08/29/95 16:30:00 UNIT 182																
100	2033.	172.F	179.F	1024.F	52.	-0.4	16.7	129.	-1.	13.5	58.7	0.583	1.61	16	915	144.
08/29/95 17:00:00 UNIT 182																
100	2039.	173.F	181.F	1028.F	52.	-0.4	16.7	129.	-3.	13.4	60.8	0.578	1.63	16	965	144.
08/29/95 17:30:00 UNIT 182																
100	2004.	170.F	178.F	1024.F	52.	-0.4	16.7	128.	-3.	13.5	57.6	0.585	1.60	17	15	145.
08/29/95 18:00:00 UNIT 182																
100	2028.	168.F	175.F	1021.F	52.	-0.4	16.7	128.	-3.	13.6	56.7	0.587	1.63	17	66	145.
08/29/95 18:30:00 UNIT 182																
100	2036.	164.F	173.F	1016.F	52.	-0.4	16.7	130.	-3.	13.8	53.8	0.592	1.64	17	117	146.
08/29/95 19:00:00 UNIT 182																
100	2041.	164.F	172.F	1016.F	52.	-0.4	16.7	128.	-3.	13.9	51.0	0.598	1.63	17	167	146.
08/29/95 19:30:00 UNIT 182																
100	2033.	163.F	170.F	1007.F	52.	-1.4	16.5	128.	-4.	13.9	49.1	0.602	1.60	17	218	147.
08/29/95 20:00:00 UNIT 182																
100	2015.	163.F	170.F	1008.F	52.	-2.0	16.4	127.	-4.	13.9	49.5	0.601	1.62	17	268	147.
08/29/95 20:30:00 UNIT 182																
100	2056.	163.F	169.F	1005.F	52.	-2.0	16.4	127.	-4.	13.9	49.2	0.602	1.61	17	318	148.
08/29/95 21:00:00 UNIT 182																
100	2051.	163.F	170.F	1008.F	52.	-2.0	16.4	127.	-3.	13.8	49.8	0.600	1.60	17	368	148.
08/29/95 21:30:00 UNIT 182																

08/29/95 22:00:00 UNIT 182	100	2032.	164.F	171.F	1010.F	52.	-2.1	16.3	127.	-3.	13.8	50.5	0.599	1.59	17	467	149.
08/29/95 22:30:00 UNIT 182	100	2023.	164.F	171.F	1008.F	52.	-2.1	16.3	127.	-3.	13.8	51.2	0.598	1.58	17	517	150.
08/29/95 23:00:00 UNIT 182	100	2065.	163.F	170.F	1007.F	52.	-2.1	16.3	127.	-3.	13.8	51.8	0.596	1.58	17	566	150.
08/29/95 23:30:00 UNIT 182	100	2040.	164.F	171.F	1005.F	52.	-2.1	16.1	125.	-3.	13.8	50.0	0.600	1.59	17	616	151.
08/30/95 00:00:00 UNIT 182	100	2054.	164.F	172.F	1006.F	52.	-2.1	16.1	126.	-3.	13.8	51.9	0.596	1.60	17	665	151.

V.R.SYSTEMS INC.

MODEL V3 S/N 182
PERMIT NO.

		ENGINE RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	UNITS	ENGINE HOURS
08/30/95 00:30:00 UNIT 182	100	2017.	164.F	171.F	1006.F	52.	-2.1	16.1	126.	-3.	13.8	51.3	0.597	1.57	17	714	152.
08/30/95 01:00:00 UNIT 182	100	2029.	164.F	171.F	1005.F	52.	-2.1	16.1	126.	-3.	13.8	52.5	0.595	1.56	17	763	152.
08/30/95 01:30:00 UNIT 182	100	2039.	164.F	171.F	1006.F	52.	-2.1	16.0	126.	-3.	13.8	52.9	0.594	1.57	17	812	153.
08/30/95 02:00:00 UNIT 182	100	2030.	164.F	171.F	1004.F	52.	-2.1	16.0	125.	-3.	13.8	51.5	0.597	1.58	17	861	153.
08/30/95 02:30:00 UNIT 182	100	2048.	164.F	170.F	1002.F	52.	-2.1	16.0	125.	-3.	13.8	51.8	0.596	1.57	17	909	154.
08/30/95 03:00:00 UNIT 182	100	2027.	165.F	171.F	1004.F	52.	-2.1	16.0	125.	-3.	13.8	52.5	0.595	1.57	17	958	154.
08/30/95 03:30:00 UNIT 182	100	2058.	162.F	170.F	1000.F	52.	-2.1	16.0	126.	-3.	13.9	50.0	0.600	1.56	18	7	155.
08/30/95 04:00:00 UNIT 182	100	2023.	163.F	168.F	999.F	52.	-2.2	15.9	126.	-3.	13.9	49.2	0.602	1.56	18	56	155.
08/30/95 04:30:00 UNIT 182	100	2025.	163.F	169.F	1002.F	52.	-2.2	15.9	126.	-3.	13.9	50.0	0.600	1.55	18	104	156.
08/30/95 05:00:00 UNIT 182	100	2048.	163.F	171.F	1003.F	52.	-2.2	15.9	126.	-3.	13.8	53.0	0.594	1.56	18	153	156.
08/30/95 05:30:00 UNIT 182	100	2043.	163.F	170.F	1004.F	52.	-2.2	15.9	125.	-3.	13.9	52.0	0.596	1.56	18	202	157.
08/30/95 06:00:00 UNIT 182	100	2027.	161.F	168.F	995.F	52.	-2.3	15.9	125.	-3.	14.0	47.8	0.604	1.57	18	250	157.
08/30/95 06:30:00 UNIT 182	100	2050.	163.F	170.F	1007.F	52.	-2.3	15.8	125.	-3.	13.8	52.9	0.594	1.56	18	299	158.
08/30/95 07:00:00 UNIT 182 stop skimming (2) test 0710 HRS	100	2006.	163.F	171.F	1008.F	52.	-2.3	15.8	125.	-2.	13.8	50.4	0.599	1.53	18	347	158.
08/30/95 07:13:52 UNIT 182	100	1875.	163.F	170.F	954.F	52.	-2.3	7.8	96.	-0.	13.8	53.1	0.594	2.37	18	371	158.
08/30/95 07:15:24 UNIT 182	100	1479.	162.F	168.F	874.F	52.	-1.8	7.7	65.	1.	13.7	55.2	0.590	1.43	18	373	158.
08/30/95 07:15:49 UNIT 182	100	1454.	161.F	167.F	845.F	52.	-1.8	7.7	65.	1.	13.7	52.9	0.594	1.36	18	374	158.
08/30/95 07:16:27 UNIT 182	100	1689.	160.F	166.F	826.F	52.	3.5	7.7	64.	1.	13.7	55.5	0.589	1.60	18	375	158.
08/30/95 07:17:07 UNIT 182	100	1803.	160.F	166.F	825.F	52.	7.7	4.0	57.	1.	13.7	51.9	0.596	1.93	18	377	158.
08/30/95 07:17:36 UNIT 182	100	1801.	160.F	166.F	836.F	52.	9.4	0.1	48.	2.	13.7	52.3	0.595	2.06	18	378	158.
08/30/95 07:18:14 UNIT 182	100	1412.	161.F	165.F	844.F	52.	13.9	-0.4	0.	2.	13.7	56.0	0.588	1.88	18	379	158.
08/30/95 07:30:00 UNIT 182	100	1848.	162.F	167.F	845.F	52.	18.7	-0.4	0.	1.	13.7	53.3	0.593	2.14	18	404	159.
08/30/95 08:00:00 UNIT 182	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

08/30/95 08:11:52 UNIT 182																
100	2154.	162.F	168.F	855.F	52.	22.1	-0.5	0.	1.	13.7	52.9	0.594	2.28	18	496	159.
08/30/95 08:23:10 UNIT 182																
100	2169.	164.F	173.F	971.F	52.	-0.3	13.8	119.	-1.	13.8	54.9	0.590	1.64	18	515	159.
08/30/95 08:30:00 UNIT 182																
100	2139.	164.F	173.F	978.F	52.	-0.3	13.8	118.	-1.	13.7	53.4	0.593	1.69	18	527	160.
08/30/95 08:44:08 UNIT 182																
100	2034.	162.F	174.F	947.F	52.	0.2	9.0	101.	-0.	13.8	51.3	0.597	2.50	18	555	160.
08/30/95 08:44:48 UNIT 182																
100	1831.	163.F	173.F	920.F	52.	1.6	5.0	80.	1.	13.7	51.5	0.597	2.24	18	557	160.

V.R.SYSTEMS INC. MODEL V3 S/N 182
PERMIT NO.

	ENGINE RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	VAC.H2O	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	UNITS	ENGINE HOURS
08/30/95 08:45:28 UNIT 182																
100	2010.	163.F	173.F	898.F	52.	7.2	3.3	71.	1.	13.7	50.2	0.600	2.20	18	558	160.
08/30/95 08:46:15 UNIT 182																
100	2018.	161.F	172.F	905.F	52.	10.9	-0.4	57.	1.	13.8	48.7	0.603	2.36	18	560	160.
08/30/95 08:46:34 UNIT 182																
100	1965.	162.F	172.F	904.F	52.	10.0	-0.4	58.	1.	13.8	51.8	0.596	2.37	18	561	160.
08/30/95 09:00:00 UNIT 182	Continue Skimming (2) test start 0910															
100	1577.	161.F	164.F	755.F	52.	15.7	-0.5	0.	2.	13.6	55.5	0.589	1.68	18	585	160.
08/30/95 09:17:58 UNIT 182																
100	2036.	162.F	163.F	815.F	52.	20.8	-0.5	0.	2.	13.8	49.2	0.602	2.35	18	616	160.
08/30/95 09:19:11 UNIT 182																
100	2179.	163.F	166.F	891.F	52.	16.2	-0.6	51.	1.	13.7	47.7	0.605	2.34	18	619	160.
08/30/95 09:23:20 UNIT 182																
100	1962.	163.F	172.F	933.F	53.	9.7	14.9	83.	-0.	13.8	91.8	0.516	0.00	18	625	160.
08/30/95 09:23:57 UNIT 182																
100	2265.	164.F	172.F	1007.F	52.	6.4	14.8	117.	-2.	13.8	50.9	0.598	0.76	18	625	160.
08/30/95 09:30:00 UNIT 182																
100	2153.	163.F	174.F	992.F	52.	-0.3	15.7	124.	-2.	13.7	49.4	0.601	1.46	18	633	161.
08/30/95 10:00:00 UNIT 182																
100	2130.	164.F	173.F	994.F	52.	-0.3	16.3	128.	-2.	13.9	48.2	0.604	1.69	18	684	161.
08/30/95 10:30:00 UNIT 182																
100	2114.	164.F	174.F	1011.F	52.	-0.3	16.9	130.	-2.	13.7	49.8	0.600	1.72	18	737	162.
08/30/95 10:47:39 UNIT 182																
100	2129.	166.F	175.F	1025.F	52.	-0.3	17.7	134.	-2.	13.8	52.0	0.596	1.83	18	770	162.
08/30/95 11:00:00 UNIT 182																
100	2107.	164.F	175.F	1024.F	52.	-0.3	17.8	133.	-2.	13.8	50.5	0.599	1.77	18	793	162.
08/30/95 11:30:00 UNIT 182																
100	2130.	166.F	175.F	1026.F	52.	-0.3	18.1	135.	-2.	13.9	50.7	0.599	1.83	18	849	163.
08/30/95 12:00:00 UNIT 182																
100	2119.	165.F	176.F	1025.F	52.	-0.3	18.2	135.	-2.	13.8	51.8	0.596	1.86	18	906	163.
08/30/95 12:30:00 UNIT 182																
100	2134.	166.F	176.F	1027.F	52.	-0.3	18.2	136.	-1.	13.8	52.7	0.595	1.85	18	963	164.
08/30/95 13:00:00 UNIT 182																
100	2107.	165.F	176.F	1033.F	52.	-0.3	18.3	136.	-1.	13.8	51.2	0.598	1.86	19	21	164.
08/30/95 13:30:00 UNIT 182																
100	2128.	166.F	177.F	1034.F	52.	-0.3	18.6	138.	-1.	13.7	54.2	0.592	1.91	19	79	165.
08/30/95 14:00:00 UNIT 182																
100	2137.	167.F	177.F	1033.F	52.	-0.3	18.6	138.	-1.	13.8	52.4	0.595	1.91	19	138	165.
08/30/95 14:30:00 UNIT 182																
100	2167.	168.F	179.F	949.F	52.	-0.3	12.9	116.	0.	13.7	51.5	0.597	2.71	19	204	166.
08/30/95 15:00:00 UNIT 182																
100	2149.	166.F	178.F	928.F	52.	-0.3	12.3	113.	0.	13.7	51.2	0.598	2.67	19	286	166.

08/30/95 15:01:27 LIMIT 302 OIL PSI 28. LOW OIL PSI SD UNIT 182
08/30/95 15:01:29 LIMIT 414 ENG TMR OVRNG ENGINE FAILED ALARM UNIT 182

¿ESTART AT: 08/30/95 15:05:33 (08/30/95 15:04:23) S5245 V2.23 .

100	3.	194.F	164.F	518.F	0.	14.0	-0.5	0.	2.	12.8	99.9	0.500	0.00	19	289	166.

¿ESTART AT: 08/30/95 15:07:20 (08/30/95 15:06:14) S5245 V2.23 .

08/30/95 15:07:23 UNIT 182

100	3.	194.F	160.F	544.F	0.	19.2	-0.5	0.	2.	12.8	99.9	0.500	0.00	19	289	166.

¿ESTART AT: 08/30/95 15:08:37 (08/30/95 15:07:53) S5245 V2.23 .

08/30/95 15:08:40 UNIT 182

100	49.	193.F	157.F	503.F	0.	23.1	-0.5	0.	-27.	12.8	18.8	0.662	0.00	19	289	166.

¿ESTART AT: 08/30/95 15:10:03 (08/30/95 15:08:55) S5245 V2.23 .

V.R.SYSTEMS INC.

MODEL V3 S/N 182
PERMIT NO.

	ENGINE	TEMPERATURE			OIL	POSITIONS		WELL FLOW		BATTERY	DUTY	PERCENT	AUXILIARY FUEL			ENGINE
	RPM	COOLANT	OIL	EXHAUST	PSI	CARB.	BYPASS	CFM-	VAC.H2O	VOLTS	CYCLE	OXYGEN	CFM	THOUSANDS-	UNITS	HOURS
08/30/95 15:10:07 UNIT 182																
100	3.	191.F	156.F	492.F	0.	23.3	-0.5	0.	2.	12.9	99.9	0.500	0.00	19	289	166.
¿ESTART AT: 08/30/95 15:13:31 (08/30/95 15:10:20) S5245 V2.23 .																
08/30/95 15:13:34 UNIT 182																
100	3.	185.F	145.F	407.F	0.	23.3	-0.5	0.	1.	12.8	99.9	0.500	0.00	19	289	166.
¿ESTART AT: 08/30/95 15:15:36 (08/30/95 15:13:40) S5245 V2.23 .																
08/30/95 15:15:39 UNIT 182																
100	0.	180.F	139.F	386.F	2.	-25.0	-25.0	0.	-401.	0.0	0.1	0.700	0.00	19	289	166.
RESTART AT: 08/30/95 15:16:45 (08/30/95 15:16:18) S5245 V2.23 .																
08/30/95 15:16:48 UNIT 182																
100	3.	176.F	137.F	386.F	0.	23.3	-0.5	0.	1.	12.9	99.9	0.500	0.00	19	289	166.
08/30/95 15:18:46 UNIT 182																
100	1819.	166.F	169.F	636.F	52.	22.0	-0.7	0.	1.	13.8	9.8	0.680	0.00	19	289	166.
08/30/95 15:21:16 UNIT 182																
100	2036.	164.F	169.F	786.F	52.	21.1	-0.8	0.	1.	13.7	49.1	0.602	1.42	19	291	166.
08/30/95 15:50:43 UNIT 182																
100	2103.	166.F	178.F	1029.F	52.	1.2	17.9	132.	-1.	13.8	53.2	0.594	1.84	19	337	167.
08/30/95 15:51:11 UNIT 182																
100	2115.	166.F	177.F	1023.F	52.	4.3	15.7	121.	-0.	13.8	53.6	0.593	1.80	19	338	167.
08/30/95 16:00:00 UNIT 182																
100	2146.	166.F	177.F	1072.F	52.	-0.4	21.6	150.	-2.	13.7	54.3	0.591	1.74	19	352	167.
08/30/95 16:30:00 UNIT 182																
100	2155.	170.F	178.F	1057.F	52.	-1.1	20.9	147.	-2.	13.7	54.3	0.591	1.97	19	406	167.
08/30/95 17:00:00 UNIT 182																
100	2157.	166.F	177.F	1044.F	52.	-1.3	20.6	145.	-2.	13.9	49.8	0.600	1.95	19	465	168.
08/30/95 17:30:00 UNIT 182																
100	2143.	166.F	176.F	1031.F	52.	-1.3	19.7	141.	-2.	13.9	48.4	0.603	1.98	19	526	168.
08/30/95 17:31:52 UNIT 182																
100	2082.	166.F	176.F	1026.F	52.	-1.2	17.9	133.	-2.	13.9	46.0	0.608	1.99	19	530	168.
08/30/95 17:32:23 UNIT 182																
100	2063.	166.F	176.F	1013.F	52.	-1.2	17.5	132.	-2.	13.9	46.6	0.607	2.04	19	531	168.
08/30/95 17:33:08 UNIT 182																
100	1896.	166.F	175.F	1011.F	52.	-0.3	12.7	114.	-0.	13.9	53.4	0.593	2.05	19	532	168.
08/30/95 17:38:04 UNIT 182																
100	2173.	166.F	174.F	992.F	52.	10.7	11.4	103.	-0.	13.9	52.1	0.596	2.09	19	542	168.
08/30/95 18:00:00 UNIT 182																
100	2149.	165.F	175.F	1025.F	52.	-0.3	18.6	136.	-2.	13.9	50.6	0.599	1.98	19	587	169.
08/30/95 19:00:00 UNIT 182																
100	2155.	164.F	172.F	1020.F	52.	-0.3	18.3	135.	-2.	14.0	49.9	0.600	1.93	19	707	170.
08/30/95 20:00:00 UNIT 182																
100	2149.	164.F	173.F	1023.F	52.	-0.3	18.0	134.	-2.	13.8	49.8	0.600	1.96	19	826	171.
08/30/95 21:00:00 UNIT 182																
100	2150.	163.F	171.F	1017.F	52.	-0.3	18.0	134.	-3.	13.9	48.1	0.604	1.92	19	946	172.
08/30/95 22:00:00 UNIT 182																
100	2023.	163.F	168.F	1000.F	52.	-0.7	15.5	124.	-3.	13.9	44.9	0.610	1.70	20	52	173.
08/30/95 23:00:00 UNIT 182																
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

08/31/95 00:00:00 UNIT 182																
100	2032.	162.F	168.F	999.F	52.	-0.7	15.5	123.	-3.	13.8	45.4	0.609	1.72	20	263	175.
08/31/95 01:00:00 UNIT 182																
100	2012.	163.F	169.F	997.F	52.	-0.7	15.5	123.	-3.	13.8	46.8	0.606	1.70	20	369	176.
08/31/95 02:00:00 UNIT 182																
100	2045.	162.F	168.F	996.F	52.	-0.7	15.5	123.	-3.	13.8	47.6	0.605	1.70	20	474	177.
08/31/95 03:00:00 UNIT 182																
100	2035.	162.F	168.F	996.F	52.	-0.7	15.5	123.	-3.	13.8	47.6	0.605	1.70	20	580	178.

V.R.SYSTEMS INC. MODEL V3 S/N 182

PERMIT NO.

ENGINE	RPM	TEMPERATURE COOLANT	OIL	EXHAUST	OIL PSI	POSITIONS CARB.	BYPASS	WELL FLOW CFM	-VAC.H20	BATTERY VOLTS	DUTY CYCLE	PERCENT OXYGEN	AUXILIARY FUEL CFM	THOUSANDS	-UNITS	ENGINE HOURS
08/31/95 04:00:00 UNIT 182																
100	2043.	163.F	168.F	995.F	52.	-0.7	15.5	123.	-3.	13.8	45.5	0.609	1.70	20	686	179.
08/31/95 05:00:00 UNIT 182																
100	2029.	162.F	168.F	994.F	52.	-0.7	15.5	123.	-3.	13.8	46.2	0.608	1.72	20	792	180.
08/31/95 06:00:00 UNIT 182																
100	2019.	163.F	168.F	997.F	52.	-0.7	15.5	123.	-3.	13.8	46.6	0.607	1.69	20	898	181.
08/31/95 06:50:11 UNIT 182	Stop Skimmer test (2) 0650 HRS															
100	1836.	163.F	168.F	973.F	52.	-0.7	7.6	93.	-1.	13.8	46.8	0.606	2.26	20	987	182.
08/31/95 06:58:42 UNIT 182																
100	1521.	159.F	160.F	743.F	52.	16.5	-0.4	0.	-0.	13.9	10.1	0.680	0.00	20	991	182.
08/31/95 07:00:00 UNIT 182																
100	1534.	159.F	159.F	726.F	52.	16.5	-0.4	0.	-0.	13.8	10.1	0.680	0.00	20	991	182.
08/31/95 07:03:39 LIMIT 414 ENG TMR 56802. ENGINE FAILED ALARM UNIT 182																
08/31/95 07:03:58 UNIT 182																
100	4.	159.F	156.F	682.F	0.	13.3	-0.4	0.	-1.	12.5	82.1	0.536	0.00	20	991	182.

APPENDIX D

SYSTEM CHECKLIST

Checklist for System Shakedown

Site: DOVER AFB, DE

Date: 21 AUG 95

Operator's Initials: JE

Equipment	Check If Okay	Comments
Liquid Ring Pump	✓	7 1/2 HP
Aqueous Effluent Transfer Pump	✓	
Oil/Water Separator	✓	
Vapor Flowmeter	✓	
Fuel Flowmeter	✓	Electric
Water Flowmeter	✓	Water totals calculated by flowrates
Emergency Shut off Float Switch	✓	
Effluent Transfer Tank	✓	
Analytical Field Instrumentation		
GasTector™ O_2/CO_2 Analyzer	✓	
TraceTector™ Hydrocarbon Analyzer	✓	
Oil/Water Interface Probe	✓	
Magnehelic Boards	✓	
Thermocouple Thermometer	✓	

APPENDIX E

DATA SHEETS FROM THE SHORT-TERM PILOT TEST

DAILY INSTRUMENT CALIBRATIONS

Meters (Serial #s): O_2: L0283 CO_2: L0283 TPH: DT019 Helium: MV4126

Date	Instrument	Gas Standard	Actual Reading	Comments	Recorded by
25 AUG 95	DT 019	4800 ppm	4800		DH
"	DT019	4800 (1:1)	2100		DH
"	L0283	20.8% O_2	20.8 %		DH
"	L0283	10.0% O_2	10.0 %		DH
"	L0283	4.0% CO_2	4.0 %		DH
26 AUG 95	DT 019	4800 ppm	4800		DH
26 AUG 95	DT019	4800 (1:1)	2100		DH
26 AUG 95	L0283 -	20.8 % O_2	20.8 %		DH
26 AUG 95	L0283	10.0 % O_2	10.2 %		DH
26 AUG 95	L0283	4.0% CO_2	4.0 %		DH
27 AUG 95	L0283	20.8% O_2	20.8 %		DH
28 AUG 95	L0283	20.8% O_2	20.8%		DH
29 AUG 95	L0283	20.8% O_2	20.8%		DH
30 AUG 95	DT 019	4800 ppm	4800 ppm		DH
30 AUG 95	DT019	4800 (1:1)	1600 ppm		DH
30 AUG 95	L0283	20.8 % O_2	20.8 %		DH
30 AUG 95	L0283	10.0 % O_2	10.3%		DH
30 AUG 95	L0283	4.0% CO_2	4.0%		GH
30 AUG 95	MV4126	1.96% He	1.9%		GH
31 AUG 95	DT019	4800 ppm	4800 ppm		GH
31 AUG 95	DT019	4800 (1:1)	2100 (x2.3)		GH
31 AUG 95	DT019	4800 (1:10)	500 (5000)		GH
31 AUG 95	L0283	20.8% O_2	20.8%		GH
31 AUG 95	L0283	10.0% O_2	10.5		GH
31 AUG 95	L0283	4.0% CO_2	4.0%		GH

ATMOSPHERIC OBSERVATIONS

Site: DOVER AFB, DE

Operators: EASTEP/HEADINGTON

Date/Time	Ambient Temperature	Relative Humidity	Barometric Pressure
24 AUG95/1528	89° F	76 %	29.38"
25 AUG95/0650	65.2° F	53 %	29.80"
25 AUG 95/1635	86.3° F	<30%	29.47"
26 AUG95/1000	79.1° F	<30%	29.84"
27 AUG95/1200	91.7° F	30%	29.57"
27 AUG95/2130	74.1° F	86%	29.64"
28 AUG 95/0715	71.3° F	77 %	29.68"
28 AUG 95/1950	71.7° F	55 %	29.70"
29 AUG95/0640	61.7° F	89%	29.75"
29AUG95/1500	91.1° F	<30%	29.34"
29 AUG 95/2015	72.3° F	66%	29.57"
30 AUG95/0640	68.0° F	78%	29.65"
30 AUG95/2045	72.2° F	69%	29.70"
31AUG95/0615	65.0° F	96%	29.71"

Baildown Test Record Sheet

Site: DOVER AFB, DE

Well Identification: WELL #344

Well Diameter (OD/ID): 2 inch ID, PVC

Date at Start of Test: 21 AUG 95

Sampler's Initials: ____

Time at Start of Test: 1155

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L
12.95	9.22	3.73	25.5 L/6.74 GAL
		Volume = 0.63 GAL	

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
0 min	11.68	9.7	1.98
95 min	12.85	9.22	3.63
365 min	12.96	9.19	3.77

FUEL AND WATER RECOVERY DATA

Site: DOVER AFB, DE

Start Date: Ø8-24-95

Test Type: SKIMMING

Operators: JON EASTED
GREG HEADINGTON

Date/Time	Time	LNAPL Recovery	Groundwater Recovery
-0-	-0-	—	—
08-24-95	45 MIN	2.2 GAL.	—
08-24-95	105	9.26	—
08-24-95	175	1.38 GAL.	—
08-24-95	335	4.2 GAL.	75 GAL.
08-24-95	365	1.3 GAL.	—
08-24-95	435	1.3 GAL.	—
08-24-95	473	0.66 GAL.	5 GAL.
08-25-95	1119	11.6 GAL.	—
08-25-95	1155	0.42 GAL.	70 GAL.
08-25-95	1202	0.8 GAL.	—
08-25-95	1238	0.8 GAL.	—
08-25-95	1318	1.11 GAL.	20 GAL.
08-25-95	1321	STOP TEST	—
	— TOTAL —		
	1321	35.02 GALS.	170 GALS.
	22.0 HRS.	(1.5 GPH)	(7.52 GPH)

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ___ of ___

Site: DOVER AFB, DE

Start Date: 25 AUG 95

Operators: Headington / Eastep

Start Time: 1300

Test Type: SLURPER

Well ID: 2 inch

Depth to Groundwater: 11.59'

Depth to Fuel: 11.23'

Depth of Tube: 11.5'

Date/Time	minutes Run Time	Vapor Extraction: Stack Dif. Pressure (in. H_2O)	Vapor Extraction: STACK FLOW ~~Carbon Drums (in. H_2O)~~	Vapor Extraction: Bi PASS Flowrate (scfm)	Pump Stack Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. Hg)	Total MAKE-UP AIR
..		0.035"	—				6" Hg	
1442	102	0.035"	21 cfm	32 cfm				53 cfm
1635	215	0.055"	26 cfm	26 cfm	28.8°	21.5"	6" Hg	52 cfm
~~2000~~	~~465~~							
2045	465	0.045"	23 cfm	26 cfm	26.5	21.5"	6" Hg	49.5 cfm
0840	1180	0.055"	26 cfm	26 cfm	29.2°	21.5"	6" Hg	52 cfm
1315	1455	0.052"	25 cfm	26 cfm	29.0°	21.5"	6" Hg	51 cfm
1845	1785	0.045"	23 cfm	26 cfm	27.4°	21.5"	6" Hg	49 cfm
1153	2711	0.07"	28 cfm	26 cfm	29.9°	22"	6" Hg	54 cfm
2130	3228	0.06"	27 cfm	27 cfm	27.4°	22"	6" Hg	54 cfm
0715	3813	0.05"	25 cfm	26 cfm	26.8°	21.5"	6" Hg	51 cfm
1950	4508	0.045"	23 cfm	27 cfm	28.0°	22"	6" Hg	50 cfm
0640	5178	0.045"	23 cfm	26 cfm	26.0°	22"	6" Hg	49 cfm

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Site: DOVER, DE. AFB

Start Date: 08-25-95

Test Type: SLURPING
WELL VACUUM = 6" Hg

Operators: JON EASTEP
GREG HEADINGTON

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
08/25/95	10 MIN.	0.53 GAL.	—
—	60	1.59 GAL.	—
—	80	0.66 GAL.	—
—	102	—	RATE = 1.81 GPM
—	153	1.32 GAL.	—
—	183	0.79 GAL.	—
1633 HRS.	213	1.0 GAL.	—
1710 HRS.	250	1.8 GAL. (1)	RATE = 2.11 GPM
1722 HRS.	262	0.93 GAL. (2)	—
1738 HRS.	278	1.58 GAL.	—
1800 HRS.	300	—	TOTAL H_2O 500 GALLON
2112 HRS.	492	—	RATE = 1.89 GPM
08/26/95	1260	25 GAL.	—
—	1350	—	RATE = 2.02 GPM
1240 HRS.	1420	2.51 GAL.	— 2.02 GPM
1845 HRS.	1785	—	RATE = 1.93 GPM
1900 HRS.	1800	16.7 GAL.	—
08/27/95	2478	16.7 GAL.	—
0900 HRS.	2538	3.96 GAL. (3)	—
1315 HRS.	2793	25.0 GAL. (3)	RATE = 1.9 GPM
1830 HRS.	3048	8.4 GAL.	—
2130 HRS.	3228	—	RATE = 2.18 GPM

NOTE: (1) REMOVED SEPERATOR FILTER
(2) CHANGED FILTER IN BAG FILTER HOUSING
(3) SKIMMED FROM WATER TANK

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Site: DOVER, DE. AFB

Start Date: 08-25-95

Test Type: SLURPING
WELL VACUUM = 6" Hg

Operators: JONI EASTEP
GREG HEADINGTON

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
08/28/95		—	—
0715 HRS	3813	18.71 GAL.	RATE = 1.92 GPM
1400 HRS	4218	10.43 GAL.	RATE = 1.93 GPM
		TOTAL AS OF 1500 HRS	
		ON 08-28-95 137.61 GALLONS	
08/28/95			
1950 HRS	4508	RATE = 3 GPH	RATE = 2.0 GPM
08/29/95			
0640 HRS	5178	RATE = 1.8 GPH	RATE = 2.0 GPM

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Site: Dover AFB

Start Date: 29 AUG 95

Test Type: SKIMMER (2)

Operators: EASTEP / HEAD

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
29AUG/0750	0	—	—
0850	60	0.68 GALLONS	Rate = 0.3 GPM
1050 – 1150	240	RATE = 0.68 GPH total = 2.72 G	—
~~1312~~ 1450	420	RATE = 0.72 GPH	—
1500 – 1550	480	RATE = 0.79 GPH	RATE = 0.3 GPM
2015	745	RATE – 0.47 GPH ~10.42 total	Rate = 0.26 GPM
30AUG95 0642–0710	1400	RATE = 0.52 GPH total = ~14.6 G	RATE = 0.25 GPM
OFF 0710	1400	total = ~14.6 Gallons	total H_2O ~392 Gallons
ON 0910	1400		
30AUG95/0946	1436	Fuel RATE = 0.75 GPH	RATE = 0.3 GPM
30AUG/1709	1879	Fuel RATE = 0.46 GPH	RATE = 0.23 GPM
30AUG/2045	2095	Fuel Rate = 0.42 GPH	RATE = 0.3 GPM
31AUG/~~0650~~ 0615	2665	Fuel RATE = 0.39 GPH	RATE = 0.34 GPM
31AUG/0650	2700	OFF Collected 6.26 Gallons Rate = ~9.3 Gallons	390 GALLONS
		total fuel collected 20.86	totAL = 782 Gallons H_2O
		total PER RATES 23.86 Gallons	
		Average = 0.53 GPH Fuel	

Bioslurping Pilot Test
(Data Sheet 1)
Well Characteristics

Site: DOVER AFB, DE

Test Type (skimmer, bioslurper vacuum extraction, drawdown): skimmer

Depth to Groundwater: Could not be determined Depth to Fuel: 10.24' Depth of Slurper Tube: 11.5'

Date at Start of Test: 24 AUG 95

Time at Start of Test: 1200 HRS Operator's Initials: GH

Date/Time	Well ID: MWA - Distance from 344 = 10'			Well ID:			Well ID:		
	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H^2O)	LNAPL Level	Water Level	Pressure (in H_2O)
0 min	10.24'								
173 min	10.265'								
335 min	10.28'								
1125 min	10.395'								
1318 min	10.40'								

Bioslurping Pilot Test
(Data Sheet 1)
Well Characteristics

Site: Dover AFB, DE

Test Type (skimmer, bioslurper vacuum extraction, drawdown): SLURPER

Depth to Groundwater: NA   Depth to Fuel: 10.36'   Depth of Slurper Tube: 11.5'

Date at Start of Test: 25AUG95

Time at Start of Test: 1300   Operator's Initials: ____

~~Date~~/Time	Well ID: MWA - 11' from 344			Well ID:			Well ID:		
	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H^2O)	LNAPL Level	Water Level	Pressure (in H_2O)
20 min	10.425'								
80 min	10.445'								
215 min	10.46'								
1320 min	10.545'								
1455 min	10.55'								
1785	10.53'								
2711	10.58'								
3228	10.63'								
3813	10.67'								
5178	10.70'								

Bioslurping Pilot Test
(Data Sheet 1)
Well Characteristics

Site: DOVER AFB, DE

Test Type (skimmer, bioslurper vacuum extraction, drawdown): 2ND SKIMMER TEST

Depth to Groundwater: — NA   Depth to Fuel: —   Depth of Slurper Tube: 11.5'

Date at Start of Test: 29 AUG 95

Time at Start of Test: 0750   Operator's Initials:

RUN TIME	Well ID: MWA - 11' from well 344			Well ID:			Well ID:		
Date/Time	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H^2O)	LNAPL Level	Water Level	Pressure (in H_2O)
345 min	10.53'								
430 min	10.50'								
745 min	10.515'								
1375 min	10.58'								
2096 min	10.68'								
2666 min	10.67'								

APPENDIX F

SOIL GAS PERMEABILITY TEST RESULTS

25 AUG 95 **Record Sheet for Air Permeability Test** 1313 HRS

Site Dover AFB	**Monitoring Point** MPA
Blower Type 7 1/2 HP Slurper	**Distance from Vent Well** 10'
Depth of Point 1 - 3.0' 2 - 6.0' 3 - 9.0'	**Recorded by** [signature]

Time	MP1	MP2	MP3	Time	MP1	MP2	MP3
0	1.25	1.20	1.15				
1 min	slurper vacuum decreased						
2 min							
3 min							
4 min							
5 min	1.00	1.05	1.05				
6 min	1.00	1.05	1.05"				
7 min	1.03	1.05	1.05				
8 min	1.03	1.05	1.05"				
9 min	1.03	1.05	1.05				
10 min	1.03	1.05	1.05				
15	1.03	1.06	1.06				
20	1.05	1.07	1.07	well VAC ~		6" Hg	
25	1.05	1.07	1.1				
28	1.05	1.07	1.07				
35							

well VAC = 7" Hg
pump head VAC = 18.5" Hg

Record Sheet for Air Permeability Test 13/3 HRS							
Site DOVER AFB				Monitoring Point MPB			
Blower Type HP SLURPER				Distance from Vent Well 20'			
Depth of Point 3' - 6' - 9'				Recorded by J. EASTEP			
Time	MP1 BLUE	MP2 ORANGE	MP3 RED	Time	MP1	MP2	MP3
~~0~~	0	0	0				
1	.005	.20	.23				
2	.005	.24	.24				
3	.005	.24	.24				
4	.005	.24	.24				
5	.01	.24	.24				
6	.01	.24	.24				
7	.01	.24	.24				
8	.01	.24	.24				
9	.01	.24	.24				
10	.01	.24	.24				
12	.01	.24	.24				
17	.01	.25	.25				
22	.01	.25	.25				
27	.01	.245	.25				
67	0.01	0.25	0.25				

Record Sheet for Air Permeability Test 1313 HRS

Site DOVER AFB	Monitoring Point MPC
Blower Type HP SLURPER	Distance from Vent Well 30'
Depth of Point 3'-6'-9'	Recorded by J. EASTEP

Time	MP1 BLUE	MP2 ORANGE	MP3 RED	Time	MP1	MP2	MP3
~~0~~	0	0	0				
10	.17	.19	.225				
15	.18	.187	.23				
27	.19	.20	.245				
34	185	.195	.24				
64	0.197	0.205	0.25				
133	0.17	0.17	0.205				

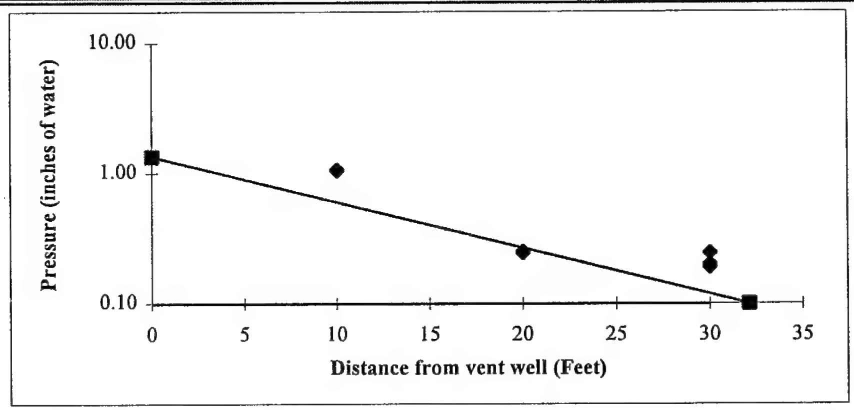
AIRPERM.RS (G462201-1001 DISK)

Radius of Influence

Site Name Dover AFB **Operator(s)** J. Eastep, G. Headington **Date:** 8/25/95

Time	Air Flow	Vacuum (inches of water)													
(min.)	(cfm)	MPA-3	MPA-6	MPA-9	MPB-3	MPB-6	MPB-9	MPC-3	MPC-6	MPC-9					red
		1.05	1.07	1.07	0.01	0.25	0.25	0.19	0.20	0.25					
Distance (ft)		10	10	10	20	20	20	30	30	30					

R_I: 32.11 ft



APPENDIX G

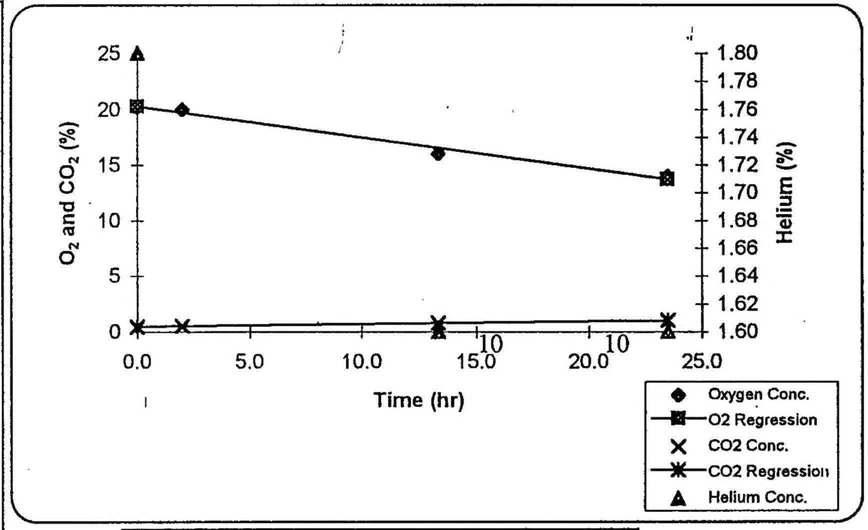
IN SITU RESPIRATION TEST RESULTS

In Situ Respiration Test

Date: 10/25/95 **Site Name:** Dover AFB, DE

Monitoring Point: C **Depth of M.P. (ft):** 9

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/30/95 7:30	0.0	20.20	0.40	1.80
8/30/95 9:30	2.0	20.00	0.50	
8/30/95 20:50	13.3	16.00	0.80	1.60
8/31/95 7:00	23.5	14.00	1.00	1.60



O_2 Utilization Rate

Ko 0.005 %/min
0.278 %/hr
6.668 %/day

Regression Lines	O_2	CO_2
Slope	-0.2778	0.0251
Intercept	20.2473	0.4315
Determination Coef.	0.9832	0.9871
No. of Data Points.	4	4

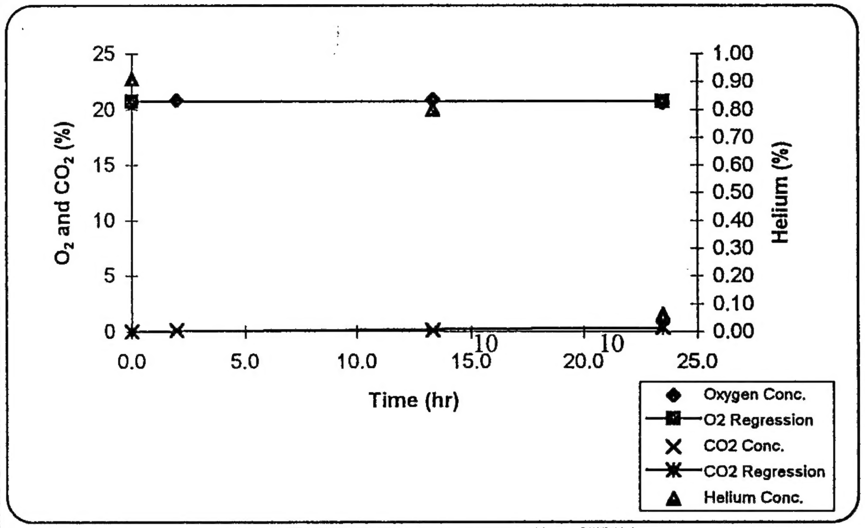
resp.xls
RT 8

In Situ Respiration Test

Date: 10/25/95 **Site Name:** Dover AFB, DE

Monitoring Point: A **Depth of M.P. (ft):** 6

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/30/95 7:30	0.0	20.60	0.00	0.91
8/30/95 9:30	2.0	20.80	0.10	
8/30/95 20:50	13.3	20.90	0.10	0.80
8/31/95 7:00	23.5	20.60	0.40	0.06



O_2 Utilization Rate

Ko	0.000 %/min
	0.001 %/hr
	0.031 %/day

Regression Lines	O_2	CO_2
Slope	-0.0013	0.0143
Intercept	20.7373	0.0111
Determination Coef.	0.0086	0.8121
No. of Data Points.	4	4

resp.xls (excel)
RT 5

In Situ Respiration Test

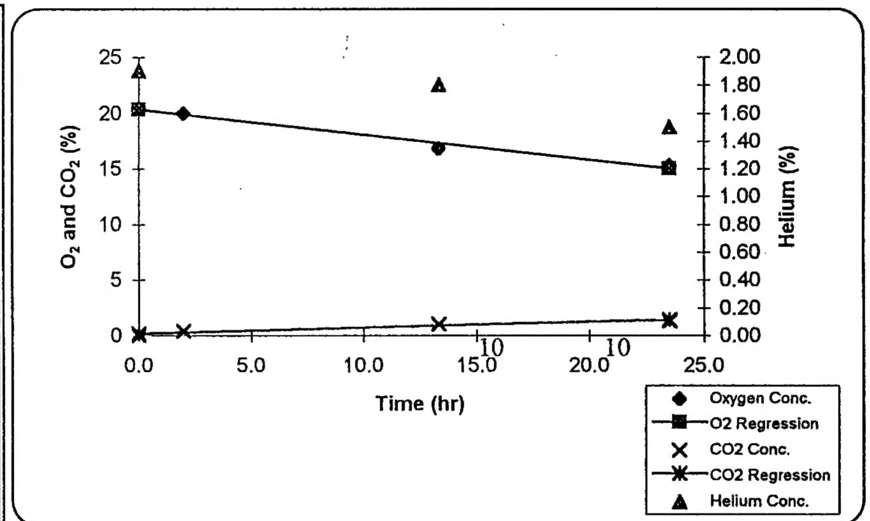
Date: 10/25/95

Site Name: Dover AFB, DE

Monitoring Point: B

Depth of M.P. (ft): 9

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/30/95 7:30	0.0	20.40	0.02	1.90
8/30/95 9:30	2.0	20.00	0.40	
8/30/95 20:50	13.3	16.80	1.00	1.80
8/31/95 7:00	23.5	15.30	1.30	1.50



O_2 Utilization Rate

Ko	0.004 %/min
	0.225 %/hr
	5.398 %/day

Regression Lines	O_2	CO_2
Slope	-0.2249	0.0512
Intercept	20.3087	0.1830
Determination Coef.	0.9802	0.9349
No. of Data Points.	4	4

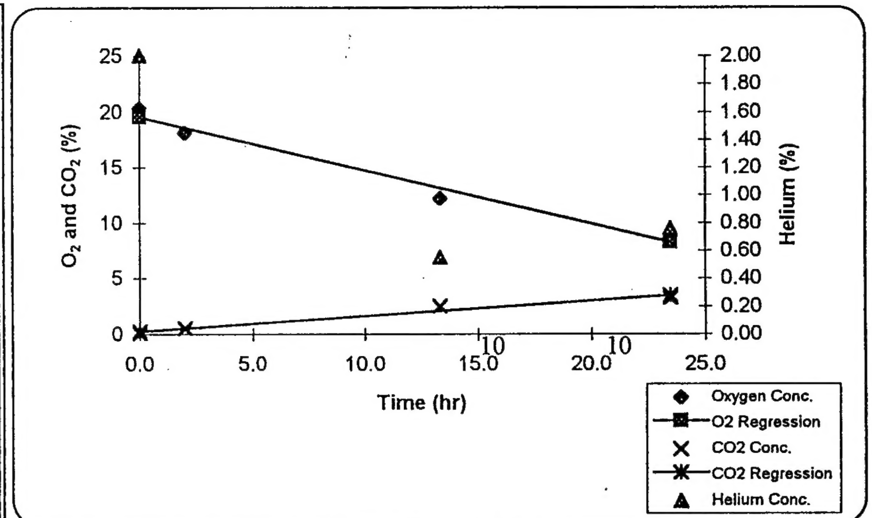
resp.xls
RT6

In Situ Respiration Test

Date: 10/25/95 **Site Name:** Dover AFB, DE

Monitoring Point: C **Depth of M.P. (ft):** 6

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/30/95 7:30	0.0	20.30	0.05	2.00
8/30/95 9:30	2.0	18.10	0.50	
8/30/95 20:50	13.3	12.20	2.50	0.55
8/31/95 7:00	23.5	8.80	3.20	0.76



O_2 Utilization Rate

Ko 0.008 %/min
0.479 %/hr
11.496 %/day

Regression Lines	O_2	CO_2
Slope	-0.4790	0.1368
Intercept	19.5002	0.2340
Determination Coef.	0.9764	0.9583
No. of Data Points.	4	4

resp. xls
RT 7